1971

An Evaluation of Diagnostic Parameters of Bekesy Audiometry.

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72-3488

GRANITZ, David Warren, 1932-
AN EVALUATION OF DIAGNOSTIC PARAMETERS
OF BÉKÉSY AUDIOMETRY.

The Louisiana State University and
Agricultural and Mechanical College,
Ph.D., 1971
Speech Pathology

University Microfilms, A XEROX Company, Ann Arbor, Michigan

AN EVALUATION OF DIAGNOSTIC PARAMETERS OF BÉKÉSY AUDIOMETRY

A Dissertation

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy

in

The Department of Speech

by
David Warren Granitz
M.A., The Ohio State University, 1959

August 1971

ACKNOWLEDGMENT

The author wishes to express his sincere appreciation to Dr. Vincent W. Byers, the director of this research, for his guidance and encouragement in the conduct of this experiment and in the preparation of the dissertation.

Appreciation is also expressed to the judges and to Dr. John L. Peterson, Dr. Robert C. Bilger, and Dr. James F. Jerger for their suggestions concerning portions of the study.

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ABSTRACT

This investigation evaluated the diagnostic value of various methods used to interpret Békésy audiograms.

A series of four independent but related experiments was devised to test specific questions about different aspects of the diagnostic significance of Békésy audiometry.

A pilot study on swingwidth revealed that a typical clinic population could meet and maintain a strict swing-width criterion of ±5 decibels. This established a realistic baseline from which a meaningful comparison and analysis of the results could be made.

The first experiment answered the question of which test mode, the sweep or the fixed frequency tracing, was the better indicator of site of pathology. The validating criterion for site of pathology was the medical diagnosis. Békésy tracings from 127 subjects were analyzed utilizing a numerical system of typing. The results indicated that both the sweep and the fixed tracings were equally successful in predicting site of pathology for subjects with normal hearing, conductive hearing impairments, and with retro-cochlear lesions. For subjects with cochlear pathologies, the fixed frequency tracings were more sensitive for indicating site of pathology.

The second experiment answered the question of which parameter of the fixed frequency tracings is the better

indicator of cochlear pathology; the difference (D) in thresholds between the interrupted and continuous tones or the swingwidth (Wc) of the continuous tone. The results indicated that there was no significant difference between the two measures in distinguishing cochlear pathology.

To determine if the efficiency of Wc could be increased, the Wc at 4000 was compared to the Wc at 500 Hz. The results indicated that the Wc at 4000 Hz was significantly narrower than at 500 Hz.

The third experiment answered the question of which test method, forward or reverse continuous tone sweep tracings, provided test results that were more easily and more reliably classified. The results indicated that only those subjects with otovestibular complaints showed a greater difference in threshold on the reverse tracing, but it was not great enough to facilitate typing Békésy audiograms.

The fourth experiment answered the question: Is the typing of Békésy audiograms an art or skill?

One hundred and seventy tracings were typed by four expert judges utilizing their qualitative method (art) of analysis. Their typings were compared to a quantitative or numerical method of analysis and the results indicated no significant difference between methods.

The results of this study showed that the efficiency of predicting the site of lesion by the typing of Békésy audiograms of etiological groups varied from excellent for the majority to only fair for the cochlear pathologies. While the fixed frequency mode was superior to the sweep mode for diagnostic value, it still missed an unwarrented number of cochlear pathologies.

A major outcome of this study is the finding that typing is amenable to numerical quantification. This moves Bekesy audiometry from the realm of clinical expertise and subjective evaluation to the domain of clinical science and objective measurement.

CHAPTER I

INTRODUCTION

Automatic audiometry, or Békésy audiometry as it is generally called, introduced a new and different piece of equipment into the field of audiology. Georg von Békésy's innovation provided a method for the subject to record his pure tone thresholds automatically and gave an estimate of threshold as a function of frequency and/or time. In effect, the audiometer took away control by the experimenter and gave the control of several dependent variables to the subject.

Békésy's audiometer automatically changes the test frequency and provides for a continuous change in intensity as controlled by the subject. The subject varies the intensity of the signal around his sensitivity threshold by alternately pressing and releasing a switch when the tone is just heard and not heard. A recording pen connected to the attenuator provides a continuous line trace of the subject's excursions around threshold.

The new audiometer's application to research and clinical settings has tended to serve different purposes. In psychoacoustic research one of its functions has been to provide an estimate of absolute threshold, as a function of either frequency or time, which is interpolated from the subject's threshold tracking behavior. For example, it has been found to be of value in the measurement of temporary threshold shift following acoustic stimulation (Byers, 1963; Hirsh and Bilger, 1955; Lierle and Reger, 1954). For differential diagnosis of auditory disorders, more emphasis had generally been placed on the characteristics of the subject's threshold tracking behavior than upon the absolute thresholds derived from it. Jerger (1960) reported that comparison of the interrupted and continuous tones revealed four basic types of patterns. These types, based upon a qualitative judgement of the patterning, or relationship, between continuous and interrupted tracings, corresponded to site of lesion within the auditory system.

This paper will emphasize only the clinical aspects of Békésy audiometry. The purpose will be to resolve and clarify the importance and diagnostic significance of Békésy audiometry in clinical audiology.

CHAPTER II

REVIEW OF THE LITERATURE

The review of the literature will focus attention on: (A) equipment, (B) independent variables, (C) dependent variables, (D) interpretations of test traces.

A. Equipment.

Békésy's original audiometer consisted of: (1) a continuously variable audio-frequency generator with a range of from 100 to 10,000 Hertz (Hz); (2) an instantly reversible motor-driven attenuator, with a range of 140 decibels, by means of which the intensity could be increased or decreased; (3) a recording pen connected to the attenuator in such a way as to record the change in intensity on a revolving drum which rotated in synchrony with the changing frequency. In operation, the motor drove the audio-frequency generator which delivered a tone to the earphones through a potentiometer.

The tone varied continuously in frequency and the motor drove a spiral gear which continuously changed the intensity of the tone by 2-decibel steps via the potentiometer. The motor was controlled by a switch operated by the subject. When the subject depressed the switch, the attenuator motor increased the intensity. When he released the switch, the motor reversed itself and the intensity was decreased. Thus, the tone, the frequency of which was continuously changing, was being increased and decreased by the subject as he pressed or released the switch. The motor, while driving the audio-frequency generator, rotated a drum so that the intensity changes were recorded on the audiogram at the proper frequencies. A complete hearing test consisted of sweeping from 100 to 10,000 Hz and took fifteen minutes. The obtained audiogram provided threshold figures for every point between these two frequencies, and the height of the excursions of the tracings indicated the subject's variability around threshold.

Reger (1952) and Reger and Kos (1952) modified Békésy's audiometer by providing for three different testing time intervals - one minute, two minutes, or four minutes per octave, enabling the five-octave frequency range of 250 Hz to 8000 Hz to be tested in five, ten or twenty minutes. The signal could be attenuated at a rate of 2, 1, or .5 decibels per second as desired.

Many of Reger's modifications were subsequently incorporated into the Grason-Stadler Model E-800 automatic audiometer. In the E-800, the test signal is generated by a continuously variable beat-frequency oscillator with a range of 100 to 10,000 Hz. The frequency range can be adjusted to meet different testing needs. A two decade range sweeps from 100 to 10,000 Hz at either of two speeds and gives information at all frequencies within this range. A two-octave tracing sweeps through any two octaves at either of two speeds, and can be used to obtain a detailed plot of a limited range for close examination when a pattern of abrupt loss occurs or a notch is seen in the sweep frequency tracing. When the chart adjustment knob is put into neutral position, the oscillator remains at a single frequency, plotting threshold as a function of time.

Throughout any of the above frequency ranges, the test signal may be presented in either a continuous or pulsed mode. An internal electronic switch performs the switching function and for the interrupted tone pulses the signal approximately 2.5 times per second. A rise and decay time of 25 milliseconds is used in shaping the switching envelope to eliminate transients. For achieving switching rates other than 2.5 interruptions per second, the electronic switch can be controlled by an external timer.

Intensity change is controlled by the subject's manipulation of the hand switch. Attenuation rates may be set at 2.5 or 5.0 decibels per second. In Bekesy's original audiometer the intensity changes were in 2 decibel-per-second steps which resulted in a detectable click at high intensities as the attenuator moved from step to step. The new Bekesy audiometer attenuates in

.25 decibel steps giving the intensity a smooth, continuous curve, thus eliminating any chance that clicks will affect threshold responses. In the slow mode of operation the attenuation rate halves (2.5 per second) and the testing time doubles to 7 minutes. A switch on the control panel permits the experimenter to override the subject's control of the hand switch. Another switch allows the examiner to increase or decrease the intensity of the test stimulus by 20 decibels in order to extend the range of the instrument when the subject's hearing is either normal or shows a profound impairment and the pen is restricted at the top or bottom of the audiogram.

For masking the contralateral ear, a noise generator built into the unit provides white noise with a spectrum falling off above 10,000 Hz. The masking intensity range is 20 to 120 decibels SPL re 0.0002 dynes/cm.^{2}, and is adjustable in 5 decibel steps. The noise generator section has connections for external filters to permit narrow-band masking. A VU meter, calibrated in decibels, is provided for calibration of both test and masking levels. A pair of dynamic air-conduction earphones (TDH-39) mounted in MX41/AR cushions are provided for stimulus presentation (Grason-Stadler, 1963a, b, c).

B. <u>Independent Variables</u>.

It was not until 1955, that much was done about studying the effects on threshold and tracking behavior resulting from changing the equipment parameters, i.e., attenuation rate, testing time, mode of stimulus tone, direction of frequency change.

Corso (1955, 1956), and Corso and Wilson (1957) studied the effects of testing time, signal mode (pulsed or continuous), signal attenuation rate and direction of frequency change (low to high/high to low frequency) on three criterial measures: (1) mean threshold values, (2) variability of response above and below mean threshold value (range of excursions), and (3) threshold test-retest reliability.

They concluded that optimal results are obtained on a Békésy-type audiometer using experienced subjects, 1.5 decibels/second attenuation rate, 11.0 minutes testing time, low to high frequency direction of sweep and either a pulsed or continuous tone.

Epstein (1960) investigated attenuation rates of 1, 2, 3, and 6 decibels per second, test time, and direction of sweep. He found a tendency for lower thresholds, especially in the higher frequencies, as the attenuation rate increased from 1 decibel per second. Regarding attenuation rate, he concluded that if too slow, the subject may tend to become bored with the listening task, but at the same time, if too fast, the subject is given no opportunity to "wait" for the tone to appear and disappear, since he is too busy listening. He did not recommend a faster test time than ten minutes as important information is missed when the frequency change is too rapid.

Other studies (Harbert & Young, 1966; Palva, 1956a; 1957a; Reger, 1952; Rodda, 1964) on the effects of varying the attenuation rate and test time have all generally agreed with the findings of Corso (1955; 1956), Corso and Wilson (1957), and Békésy (1960), i.e., these changes affect amplitude of swing and have very little if any effect on threshold values. According to Corso, "neither testing time nor attenuation rate is a real factor in the determination of threshold values. . . Also [the] interaction effects of testing time and attenuation rate are nonsignificant (Corso, 1955, p. 650)." He stated in a later article (1957, p. 724):

> It would seem that a more valid estimate of threshold is obtained when a fast testing time is combined with a fast [attenuation] rate, or a slow time with a slow rate. Optimal results seem to depend upon some consistency between the rate at which the tone increases or decreases in intensity and the rate at which the frequency range is swept.

The current E-800 audiometer meets this criterion by combining a slow attenuation rate (2.5 decibels with a slow test time (7 minutes) or a fast attenuation rate (5.0 decibels) with a fast test time (3½ minutes).

Bradford and Goetzinger (1964) studied the relation of interrupted and continuous tone thresholds at 4000 Hz only, and found that interrupted tone thresholds were approximately 10 to 12 decibels better, but only when the continuous tone was presented first and the interrupted tone second. When the order was reversed (interrupted first, continuous second), there was no difference between thresholds. This finding substantiates Jerger's (1960) diagnostic use of the interrupted/continuous tone fixed frequency tracing order, at least for 4000 Hz. As mentioned earlier, Corso and Wilson (1957) also found no difference in thresholds for interrupted and continuous tones.

Since Békésy audiograms are normally obtained with the interrupted tone first, normals should not show a significant difference between thresholds (Burns & Hinchcliffe, 1957; Corso, 1955; Harris, 1964; Jerger, 1962b; Price, 1963; Rodda, 1964).

A reverse tracing is one in which the subject tracks threshold from the high frequencies to the low frequencies, which is simply a reverse of the normal procedure. Epstein (1960) tested a sample of fifteen subjects utilizing a reversed continuous tone sweep frequency tracing over the

2000-4000 Hz octave range and found that in every instance the variability around threshold was less and thresholds were better at 3000 Hz for the forward tracing than for the reverse tracing. Rose (1962) also found that reverse tracings showed greater separation of interrupted and continuous tones than forward tracings. In many cases the reverse tracing showed a separation that had not appeared in the forward tracing.

Harbert and Young (1962) found that from 1500 to 10,000 Hz thresholds are distinctly better for tracings from high to low frequency. In a later article (1967) in which reverse tracings were again obtained, they came to the same conclusion.

C. Dependent Variables.

When Békésy introduced his audiometer in 1947, lack of standardization prompted questions not only in regard to the independent variables, but to the dependent variables as well.

Questions such as: How do human factors such as reaction time, affect test results? In regard to this question Békésy stated ". . . The reaction time for pressing the key is about 0.2 seconds (1960, p. 84)," and concluded that this time would not have any effect on the results. According to Lundborg (1952) and Siegenthaler (1961), the proportion of variance in relation to reaction time is insignificant. It appears reasonable to assume that reaction time has very little effect on the tracings.

A more important question to consider is that regarding instructions and the subject's introduction to the task. Békésy (1947) did not mention specific instructions other than the fact that the subject was told to press the switch when he did not hear the tone and to release the switch when he did. The clinician has a choice of three sets of instructions to introduce the subject to his task. The first, introduced by Corso (1955; 1956) instructs the subject to press and release the switch so that the tone is always just barely audible. The second set, and possibly the most widely used (Jerger, 1960), instructs the subject to press the switch when the tone is just heard and release it when it is just not heard. Harbert and Young (1964) and others (Pestalozza & Cioce, 1962; Sorensen, 1962) have suggested a third set after finding that in order to get maximum sensitivity from the fixed steady tone tracings, the subject be specifically instructed to respond to the test frequency only so long as it is subjectively tonal in quality.

The procedure normally utilized to introduce a subject to Békésy audiometry includes verbal instructions followed by a short practice session to acquaint him with the task. Immediately following the brief introduction, and with no further reinforcement, threshold is recorded. The resultant tracing is based solely on whatever criteria the subject sets up for himself according to his interpretation of the instructions. Swing widths of 1.5 to 30 decibels have been reported in the literature (Table I) and Epstein (1960) has stated that there definitely seems to be "wide swingers" and "narrow swingers" within the normal hearing population.

Training the subject to perform his task, not just satisfactorily, but to optimum performance, is one of the most important functions the examiner has in Bekesy audiometry. According to Reger, "The testing skill of the examiner is limited to instructing the subject how to take the test and to adjusting the instrument's controls (1952, p. 1334)." Palva stated, "If the subject does not

TABLE I

SUMMARY OF AVAILABLE DATA ON EXCURSION SIZE AMONG NORMALS

ACCORDING TO VARIABLES IN BÉKÉSY AUDIOMETRIC PROCEDURE.

Source	Tone Presentation	Attenuation Rate in dB/sec.	Sweep/Fixed	Excursion Size in dB Range
Békésy (1947)	Continuous	1.5	Sweep	8-12
		2.3	Sweep	10-15
Corso (1955)	Continuous	0.5	Sweep	6.3 (mean)
		1.0	Sweep	6.7 (mean)
		2.0	Sweep	8.8 (mean)
Epstein (1960)	Continuous	1.0	Sweep	4-9
		2.0	Sweep	5-17
		3.0	Sweep	8-15
		4.0	Sweep	10-30
Grayson (1967)	Pulsed	2.5	Sweep	1.5-24
	Continuous	2.5	Sweep	1-23
Harbert and Young (1966)	Pulsed/cont.	5.0	Sweep	13.0 (mean)
Jerger (1962b)	Pulsed/cont.	2.5	Sweep	7.4 (mean)
Landes (1968)	Continuous	2.5	Fixed	5.6-12.0
Lundborg (1952)	Continuous	2.3	Sweep	6-9
Muma and Siegenthaler (1966)	Pulsed/cont.	2.5/5.0	Fixed	2-29
Palva (1956a)	Continuous	2.3	Sweep	5-15
Palva (1957b)	10/sec.pulse	2.3	Sweep	7-10
Reger (1952)	Continuous	1.0	Sweep	6-8
		2.0	Sweep	6-8
Siegenthaler (1961)	Continuous	2.5	Fixed	1.7-17.4 (mean)
Stark (1965)	Pulsed	2.5	Fixed	4-27
	Continuous	2.5	Fixed	1.5-30
Suzuki and Kubota (1966)	Pulsed	2.0	Fixed	3.5-10
	Continuous	2.0	Fixed	3-9

fully understand his share of the test, there is little hope for accuracy in the results (1956b, p. 1525)."

D. Interpretation of Results.

According to Hirsh, "One measure is not sufficient for a meaningful threshold (1952, p. 115)." Stevens states that "threshold is derived using the average of settings (1963, p. 43)." According to these definitions, full-range sweep tracings have the disadvantage in that the frequency is always changing and threshold is determined from only one crossing of threshold at any one particular frequency. Harris (1964) and others (Békésy, 1960; Burns, 1957; Corso, 1955; Jerger, 1962b; Price, 1963) have found that the mid-points of the excursions correlate quite well with laboratory studies which established minimum audible pressures and with values proposed by the international standard for audiometric zero.

Between 1947, when Békésy introduced his audiometer, and 1960, when Jerger's article appeared, experimenters were interested in three features of the tracings. First, the recording of a threshold as a continuous function of frequency permitted gaps or irregularities to be seen in a subject's audiogram in frequency regions that were not tested when only standard audiometric frequencies were used. Second, the width or variability in the tracing was thought to be related to the kind of hearing disorder involved. Third was the ability of the ear to handle a signal over time. Békésy considered variability about threshold to be a kind of difference limen at threshold.

He pointed out that a subject's tracing would be unusually narrow (small difference limen) at those frequencies where recruitment was present (Hirsh, 1962). He reasoned that an ear sensitive to loudness would more rapidly hear an increase in intensity and thus release the button to lower the intensity sooner. Likewise, a given reduction in intensity would be heard faster and the subject would press the button sooner, raising the intensity. This would produce the smaller DL (difference limen) and point up the recruitment. When Reger introduced his version of the Békésy type audiometer in 1952, he stated that it ". . . inherently demonstrates recruitment . . . [since] intensity DL is more accute in individuals who have recruitment (1952, p. 1333)." He felt that recruitment testing could be accomplished without special instructions or equipment, and could be applied to all kinds of hearing impairments.

The most notable study of the subsequent papers (Bangs, 1953; Landes, 1958; Palva, 1956b; 1957a, b) dealing primarily with the amplitude aspect of audiometric tracings, was done by Lundborg (1952). He attempted to classify Békésy tracings obtained on 50 normals, 25 cases of acoustic trauma, 26 cases of Meniere's disease, and 21 cases of diverse retrocochlear lesions. He classified the tracings according to trace width and found that there appeared to be a rather precise relation between trace width traced for a continuous tone and site of lesion. His classification consisted of four types ranging from normal excursions not exhibiting recruitment to abnormally small excursions showing recruitment.

There appears to be a relation between the type of Békésy tracing and site of lesion. Markedly reduced amplitude seems characteristic in cases with presumably cochlear lesion (acoustic trauma and Meniere's disease) but characteristically absent in the normal hearing and retrocochlear lesion groups.

Reger and Kos (1952) contend that measurements of recruitment at high intensity levels are contaminated by threshold shifts (adaptation) in the pathological ear and attempting to measure the degree of recruitment under such conditions is "analagous to trying to measure the height of a horse while it's running (p.818)." They believed that Békésy-type audiometry presented a technique by means of which simultaneous measurement of temporary threshold shift and recruitment is possible.

Hirsh, Palva, and Goodman (1954) are among those who disagreed with Békésy's contention that the excursions in amplitude around threshold is representative of a difference limen which in turn is associated with recruitment. To them, automatic audiometry was not a measure of the intensity difference limen but simply a measure of the variability about the absolute threshold. Regarding the relation between difference limen for intensity and loudness, they said that just because a given intensity change represents a bigger loudness change for a subject with recruitment, this does not mean that the intensity change is more easily detected or contain the same number of discernable steps for the two. Landes in 1958, and Epstein in 1960, lend support to this by stating that subjects respond to growth of loudness rather than DL's. Palva (1956b, pp. 1537-1539) stated:

> The width of excursions demonstrates directly the amount of variability around threshold as a function of time . . . Békésy-type audiometry can never replace ordinary audiometry combined with Fowler's (1928) or Reger's (1936) balance tests. One is probably not mislead in cases where small threshold variability is interpreted as to mean recruitment, but one misses equally many cases showing recruitment in the proper tests but failing to show it in the form of small threshold variability. . . It is necessary to work on higher sensation levels [such as is used in Fowler's and Reger's tests for recruitment] if successful results are expected in all cases.

Harbert and Young (1962) reported that the decrease in width of the tracing in sensorineural problems did not necessarily suggest the presence of recruitment, but probably indicated a kind of abnormal adaptation. Bilger (1965) contended that the variability around threshold in fixed frequency tracings uniquely separates two populations (cochlear and non-cochlear pathology).

In 1948, Dix, Hallpike, and Hood reported the absence of recruitment in subjects having an eighth nerve tumor. Reger and Kos (1952) confirmed this and also noted a shift in the threshold when a continuous tone was presented. In 1953, Dix and Hood interpreted the shifts to be a reversal of recruitment and a sign of end organ lesion.

Until recently only the width of the tracking pattern was given consideration in audiologic diagnosis. In 1960, Jerger demonstrated that if the tracking patterns for interrupted and continuous tones are compared, then there is diagnostic significance to the difference in absolute thresholds as well as in the differences between width of the tracking pattern for the two modes of tone presentation.

Jerger's study reported the relation between Békésy tracings and site of lesion within the auditory system for 434 subjects. He was not concerned whether Békésy audiometry related to loudness recruitment, but how it related to site of lesion within the auditory system. All of the tracings were obtained with a single Békésy audiometer (Grason-Stadler, Model E-800). The rate of attenuation change was 2.5 decibels per second, and the rate of frequency change was one octave per minute. The test signal was either continuous or periodically interrupted in time. In the latter case, the interruption rate was 2.5 ips. Two types of tracings were obtained; a conventional or sweep tracing, and a fixed frequency tracing. In the sweep tracings, the frequency of the test signal moved gradually upward from 100 to 10,000 Hz. In the fixed-frequency tracings the frequency was preset and never changed as the subject traced his threshold over a three-minute period. Initially Jerger tried to analyze and score the Békésy audiograms quantitatively. Various indices, such as the number of threshold crossings per quarter octave, width of the continuous tone tracing in decibels, the difference between tracing width at high and low frequencies, the difference between continuous and interrupted tone tracing midpoints, were evaluated, all with discouraging results. He reported that it soon became apparent that the range of individual variability on any absolute aspect of the Békésy audiogram could be quite substantial. On the other hand, he felt that a qualitative judgment of the patterning or relation between the interrupted and the continuous tone tracings seemed to have important diagnostic value.

On the basis of the tracings he felt that four basic types of relations could be noted, labelled type I, type

II, type III, and type IV. These are illustrated in Figure I.

An inspection of the audiograms reveals that the type I Békésy tracing is characterized by an interweaving of the continuous and interrupted tone tracings, and by a tracing width which is constant over frequency and averages about 10 decibels. The fixed frequency tracing for the type I audiogram is reflected in two interweaving horizontal tracings.

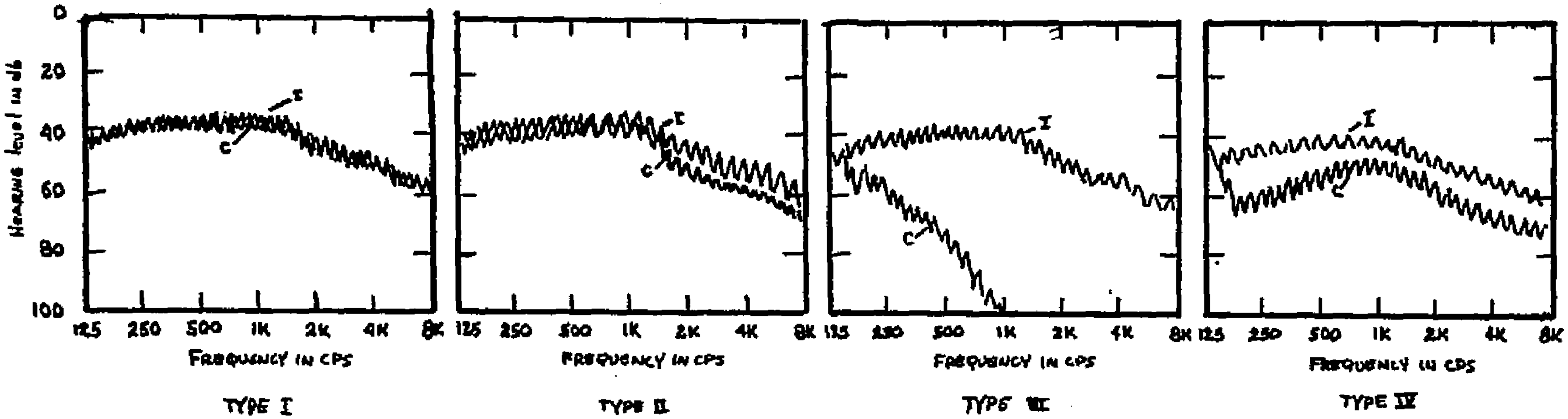
The type II tracing differs from the type I in two respects. First, the continuous tone tracing drops below the interrupted tone tracing at high frequencies, but never to a substantial extent. The gap seldom exceeds 20 decibels, and ordinarily does not appear at frequencies below 1000 Hz. Second, the width or amplitude of the continuous tone tracing is often quite small (3 to 5) decibels) in the higher frequencies. The fixed frequency for the type II, the interrupted tone tracing, is horizontal and of normal width, but the continuous tone tracing drops from 5 to 20 decibels below the interrupted tone within the first minute; thereafter, it maintains a fairly stable level.

Type III tracings show a sharp contrast to the types I and II. The continuous tone tracing drops below the interrupted tone to a remarkable degree. Also, the two curves may diverge at relatively low frequencies (100 to 500 cps). The continuous tone threshold keeps

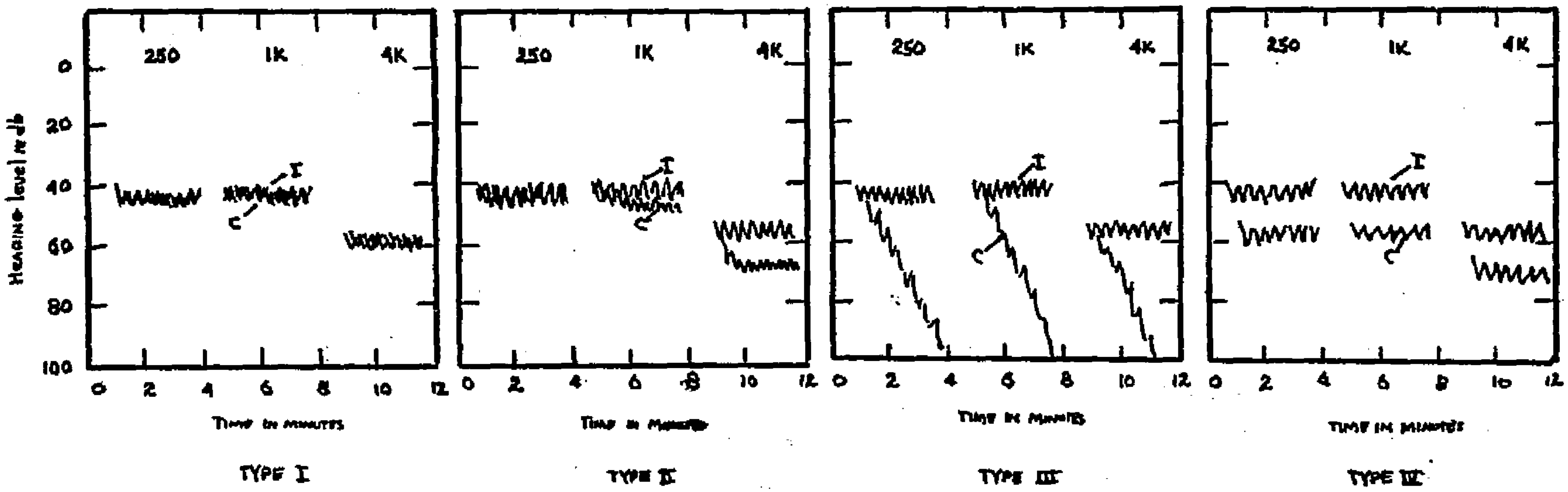
Figure I

FOUR BASIC TYPES OF BÉKÉSY AUDIOGRAMS ACCORDING TO JERGER, 1960.

Full Range Sweep Frequency Tracings



Fixed Frequency Tracings



getting worse until it gets beyond the limits of the audiometer. In type III fixed frequency tracings, the interrupted tone tracing is horizontal, but the continuous tone tracing drops very rapidly and ordinarily does not stabilize at all. A 40 to 50 decibel drop within as little as 60 seconds is not unusual.

The type IV tracing resembles type II, but differs in one important respect. The continuous tone tracing consistantly falls below the interrupted tone tracing at frequencies below 500 Hz. The tracing width may or may not become abnormally small, which may cause this type to be confused with the type II. The distinguishing feature occurring in both conventional and fixed frequency tracings is the gap between the continuous and interrupted tones at relatively low frequencies (100 to 500 Hz).

Type IV tracings differ from type III tracings in that the continuous tone ordinarily does not show a precipitous drop over time. Most of the tracings fit into one of these four categories. For one reason or another some did not appear to fit any of the four classic patterns and had to be approximated as to type.

In order to study the generality of the apparent relation between Békésy tracing types and site of lesion within the auditory system, the audiograms were grouped together according to type and matched with the presumed etiology of the subjects exhibiting them.

Jerger found that in lesions of the middle ear (otosclerosis, otitis media) a type I tracing predominated. In cochlear lesions (Meniere's, noise induced loss) type II predominates, although some fall into the type I category. In eighth nerve lesions (acoustic tumors) type III and IV tracings predominate. These results suggest a strong relation between type of Békésy tracing and site of lesion (1960).

In 1964a, Owens investigated further the implications of Békésy audiometry for predicting site of lesion. He stated that because preliminary testing substantiated Jerger's (1960) findings that the interrupted and continuous tone tracings overlap completely in normal hearing and in hearing loss due to middle ear pathology, he would report only the findings related to cochlear and retrocochlear lesions. He used 92 subjects with cochlear lesion, 20 subjects with retrocochlear lesion, and two subjects with both cochlear and retrocochlear lesions. Owens' findings indicated that types I and II tracings invariably accompanied cochlear lesions, but in two instances they camouflaged eighth nerve lesions. He indicated that the type I pattern is observed in conductive, normal, or cochlear lesions. He further observed that the type II may fall off, but at higher frequencies than Jerger indicated. He pointed out several variations of the type II which may occur. He felt that the type III pattern was characteristic of eighth nerve lesions. His findings differ with Jerger's in that he did not observe the existance of the type IV tracing in cases of retrocochlear lesions. Owens concluded that observed limitations of Békésy tracings detracted little from their importance in early detection of eighth nerve tumor. In a more recent study, Owens (1965) indicated that type II and type III Békésy tracings can be predicted from fixed frequency pure tone decay tests.

In contrast to data supporting the premise that site of lesion can best be determined by the difference between the absolute thresholds for the continuous and interrupted tones on the full range sweep tracings, Bilger (1965) has suggested that the width of the Békésy tracing around the threshold for the continuous tone is an adequate definition of a non-normal population and provides the only basis for reliable classification of fixed frequency Békésy audiograms into the categories of pathological or normal cochlear function. When he attempted to define cochlear pathology on the width of the continuous tone alone, a reliability coefficient of .82 was obtained. When the difference between continuous and interrupted tones was incorporated, the coefficient dropped to .59. He concluded that utilizing the difference decreases the reliability of the classification.

Bilger, Hopkinson, and Richardson (1966) stated that cochlear lesions are better defined by fixed frequency tracings than full range sweep tracings when attempts are made to determine how much if any cochlear overlay is present in conductive losses. Harbert and Young stated essentially the same thing when discussing retro-cochlear involvement and the significance of auditory adaptations: "Sweep frequency Békésy tracings give no clue to the abnormal adaptation demonstrable by fixed frequency tracings (1964, p. 55)."

In order to eliminate some of the existing problems of classification with the four types, and to provide some standardization of reporting Békésy findings, Hopkinson suggests:

1. Broader interpretation of the problems identified by a type IV.
2. Interpretation of types II and IV based on fixed frequency tracings.
3. For tracings confounded by a combination of characteristics of different types, the use of descriptive terms giving details regarding degree of separation and width of swing rather than a specific classification (1966, p. 80).

Other uses of the Békésy audiometer have been described by Hood, Campbell, and Hutton (1964) and their Békésy ascending, descending gap evaluation (BADGE) procedure. Watson and Voots (1964) reported a type of

Stenger test. Lezak, Siegenthaler, and David (1964) used Békésy audiometry to establish the subject's speech reception threshold.

CHAPTER III

STATEMENT OF THE PROBLEM

The review of the literature indicates that there are conflicting studies on the importance and significance of the various indices used to interpret Békésy audiograms for specifying the site of auditory lesions. Also, the efficiency of Jerger's typings appears to be weakened by his own report that his categories do not clearly separate pathological entities, nor always specify correctly the site of lesion. For example, Meniere's and acoustic trauma, cochlear pathologies, may be either a Type I or Type II. Acoustic neuroma, a retrocochlear pathology, may be either Type III or Type IV. This is probably the reason for Jerger (1965) stating that no one auditory test is sufficient for audiologic diagnosis, and suggested a test battery for specifying the site of lesion.

In essence, it appears that Békésy audiometry is a valuable clinic tool. The main focus of this study is an evaluation of the diagnostic value of Békésy audiometry. This appears essential before the overall question of whether more reliable and/or valid information can be obtained from Békésy audiometry than is presently being obtained. Because no one study could answer this question, a series of four independent but related experiments was devised to test specific questions about different aspects of the diagnostic significance of Békésy audiometry.

The question for each experiment is as follows:

Question 1: Which parameter, fixed or sweep tracing, is the better indicator of the site of pathology?

Question 2: Which parameter, the difference (D) between interrupted and continuous tone tracing or the width (Wc) of the continuous tone tracing is the better indicator of cochlear pathology?

Question 3: Which procedure, the forward or the reverse continuous tone tracing, provides test results that are more easily and more reliably classified by Granitz' classification of Békésy tracings?

Question 4: Is the typing of Békésy audiograms art or skill? Art is defined as being subjective and qualitative and skill is defined as objective and quantifiable.

CHAPTER IV

PROCEDURE

The following was the general procedure for all subjects.

A. Tests.

Each subject had the following tests administered:

1. Pure tone air and bone conduction audiometry (Carhart & Jerger, 1959).
2. Speech reception thresholds utilizing live-voice presentation of list 1-a from the Psycho-Acoustic Laboratory Auditory Test Number 9 (Hudgins, Hawkins, Karlin & Stevens, 1947).
3. Speech discrimination tests were tape recordings of Central Institute for the Deaf Auditory Test W-22 (Hirsh, Davis, Silverman, Reynolds, Eldert & Benson, 1952). The test was administered at 40 decibels sensation level (re: the speech reception threshold) in quiet and noise using half-lists which have the same reliability as whole-lists (Elpern, 1961; Resnick, 1962; and Tobias, 1964). The signal to noise ratio during discrimination in noise was plus 8 decibels. The noise signal was calibrated broad-band white noise produced by the Grason-Stadler speech audiometer.
4. Békésy Audiometry.
   a. Full range sweep tests using interrupted and continuous tones.

b. Fixed frequency tests run at 500, 2000, and 4000 Hz.

The sweep and fixed frequency tracings were typed either I, II, III, or IV, according to a numerical or quantitative system adapted from Jerger's (1960) description of the relationship between the interrupted and continuous tone tracings (Appendix D).

The following tests were included as part of the diagnostic test battery normally administered to subjects referred to the clinic because of an otovestibular complaint.

5. Short Increment Sensitivity Index (SISI) (Jerger, Shedd & Harford, 1959).
6. Alternate Binaural Loudness Balance (ABLB) (Fowler, 1928).
7. Tone Decay test (Owens, 1964b).
8. Alternate Monaural Loudness Balance (AMLB) (Reger, 1936).

B. Medical Evaluation.

Since the medical diagnosis was to serve as the validating criterion, all subjects were seen by an otolaryngologist. When possible or necessary subjects were also seen by a neurologist, a radiologist, and for electronystagmography (ENG). Reports were taken from the subjects' medical records. The diagnosis for the ENT etiology was taken either from the doctor at the time the subject was seen, or from the medical record after the evaluation had been completed.

C. Instructions.

See Appendix C.

D. Facilities and Equipment.

Data were collected at the University of Texas Medical School Audiology and Speech Clinic,Galveston branch.

All tests were administered in a double wall, two-room Industrial Acoustics Corporation Test Booth, Model 1204-A, Pure tone audiometry was conducted with a Maico diagnostic audiometer, Model MA8A. Masking, when necessary, was provided by a Beltone Narrow band masking unit, Model NB102. Speech reception thresholds were presented through a Grason-Stadler Speech Audiometer, Model 162. Tape recorded speech discrimination tests were played on an Ampex Tape recorder, Model 602 through the Grason-Stadler Speech Audiometer, Model 162. Békésy tracings were made on a Grason-Stadler Békésy Audiometer, Model E-800. All Békésy tracings were made with the attenuation rate set at 2.5 decibels per second. Total time to sweep from 100 Hz to 8000 Hz was 6 2/3 minutes. The interrupted tone was pulsed 2½ times each second. Masking during Békésy audiometry was provided by the noise generator built into the E-800. Transducers on each piece of equipment consisted of a pair of dynamic air-conduction earphones (TDH-39) mounted in MX41/AR cushions. All equipment was calibrated to the International Standards Organization (ISO) 1964 standard.

CHAPTER V

PLAN OF THE INVESTIGATION

The total investigation consisted of four separate but interrelated questions. Each investigation is presented as a separate experiment, which has the following format: Section I: History - a synopsis of the pertinent literature and rationale for the question asked; Section II: The statement of the problem; Section III: Procedure - details the subjects, method and design of the experiment; Section IV: Results - statistical analysis of the data; and, Section V: Summary and conclusion - a brief paragraph summarizing the pertinent statistical findings and the significance of the results.

Prior to running the experiments it was necessary to determine if swingwidth, a possible confounding variable, could be controlled by instructions given to the subjects. Jerger (1960) stated that excessive swingwidth obscured the relation between C and I, and the review of the literature showed that subjects' swingwidths varied from 1.5 decibels to 30 decibels. Since the variability of swingwidth could obliterate any meaningful comparison between the variables to be studied in the four experiments, a pilot study was necessary to determine if clinical subjects could perform to criterial measures on Békésy audiometry. Normal swingwidth is reported to be 7-10 decibels (Hirsh, 1962). The results of the pilot study, Appendix A, indicate that a clinical population can meet and maintain a ±5 decibel swingwidth on Békésy audiometry. The major advantage of the pilot study is the establishment of a realistic baseline from which the variables and the results of the following experiments can be meaningfully compared and analyzed.

EXPERIMENT 1

History.

Békésy tracings are currently being typed by interrupted and continuous tones in a full range sweep frequency mode and in a fixed frequency mode. The literature indicates that approximately one-half are done in the sweep mode and the other half in the fixed mode.

Most clinical audiologists using Jerger's classification system forget that his types are based on only the full range sweep frequency tracings. He stated (1965) that fixed frequency tracings can be obtained if desired, but to add supplemental information only (p. 302).

Owens (1965) on the other hand indicated that Békésy types can be predicted from fixed frequency tests more precisely than from the full range sweep tracings.

Bilger, et al. (1966), stated that cochlear lesions are better defined by fixed frequency tracings than full range sweep tracings when attempts are made to determine if any cochlear overlay is present in conductive losses. Harbert and Young (1964) stated essentially the same thing when discussing retrocochlear involvement and the significance of auditory adaptation: "Sweep frequency Békésy tracings give no clue to the abnormal adaptation demonstrable by fixed frequency tracings (p. 55)."

Obviously there is a difference of opinion among the experts concerning the relative merits of sweep versus fixed frequency tracings.

Statement of the Problem.

This experiment was designed to determine whether the full range sweep frequency tracing or the fixed frequency tracing is the better indicator of the site of pathology.

Null Hypothesis. There is no difference in using full range sweep frequency and fixed frequency tracings for determining site of pathology.

Procedure.

One hundred and twenty-seven (127) subjects referred to the University of Texas Medical School Audiology and Speech Clinic had full range sweep and fixed frequency Békésy audiometry administered as part of a larger battery of auditory tests.

Subjects were grouped according to site of pathology by the medical diagnosis. (Table II).

TABLE II

GROUPING OF SUBJECTS ACCORDING TO SITE OF LESION BY MEDICAL DIAGNOSIS.

Normals	16
Conductives (Middle Ear)	10
Mixed	6
Cochlear	44
Retrocochlear	6
Unknown	45
TOTAL	127

In the interrupted and continuous tone full range sweep tracings, the frequency of the test signal moved upward from 100 to 10,000 Hz. During fixed frequency tracings, each frequency (500, 2000, 4000 Hz) was preset and never changed while the subject traced his threshold for two minutes for both the interrupted and the continuous tones.

Results.

Separate typing was done for the full range sweep and the fixed frequency tracings for each subject. The results of this classification for both modes of testing for the diagnostic categories are displayed in Table III.

It is immediately apparent from the Table that the typings for normals, conductives, and retrocochlears are identical for both the sweep and fixed tracings.

To determine if there was a difference in typing between sweep and fixed modes, the data were placed in a 4 X 4 contingency table for analysis by chi square. The results of this classification are shown in Table IV.

The chi square was significant beyond the .01 level of confidence. There is obviously a difference in typing between sweep and fixed modes. Table III indicates the difference is not for the categories of normals, conductives,

TABLE III

TYPING OF FULL RANGE AND FIXED FREQUENCY BÉKÉSY AUDIOGRAMS

BY SITE OF PATHOLOGY.

Classification		Type	Normal	Conductive	Mixed	Cochlear	Retro-cochlear	Unknown	Totals
			ENT Classification						
Classification	Sweep	I	16	10	6	33		28	93
		II				8		16	24
		III					6		6
		IV				3		1	4
	Fixed	I	16	10	5	12		16	59
		II			1	27		29	57
		III					6		6
		IV				5			5
		Totals	16	10	6	44	6	45	127

Total N = 127

mixed or retrocochlears. The normals, conductives and mixed show a type I tracing. The retrocochlears show a type III tracing. Examination of Table IV indicates the primary area of disagreement is between type I and type II tracing. This obviously has to occur for the cochlear pathology and for the unknown pathology.

TABLE IV

COMPARISON OF CLASSIFICATIONS BASED UPON FULL RANGE AND FIXED FREQUENCY BÉKÉSY TRACINGS.

		Classification of Full Range Tracings				
		I	II	III	IV	TOTALS
Classification of Fixed Frequency Tracings	I	55	4			59
	II	36	19		2	57
	III			6		6
	IV	2	1		2	5
TOTALS		93	24	6	4	127

Chi square = 166.08 Level of significance .01 - 6.64

To determine where the difference in typing occurs, a contingency table for the cochlear pathology group and for the unknown pathology group were run for chi square analysis. The analysis for the cochlear pathology is shown in Table V. The analysis for the cochlear group indicates there is a significant difference in typing between the fixed and sweep modes for indicating cochlear pathology.

The analysis for the unknown group is shown in Table VI.

TABLE V

COMPARISON OF CLASSIFICATION BASED UPON FULL RANGE AND FIXED FREQUENCY BÉKÉSY TRACINGS FOR COCHLEAR HEARING IMPAIRMENTS.

		Classification of Full Range Tracings			
		I	II	IV	TOTALS
Classification of Fixed Frequency Tracings	I	12			12
	II	19	7	1	27
	IV	2	1	2	5
	TOTALS	33	8	3	44

Chi square = 14.17 Level of significance .01 = 6.64

TABLE VI

COMPARISON OF CLASSIFICATION BASED UPON FULL RANGE AND FIXED FREQUENCY BÉKÉSY TRACINGS FOR UNKNOWN GROUP.

		Classification of Full Range Tracings			
		I	II	IV	TOTALS
Classification of Fixed Frequency Tracings	I	12	4		16
	II	16	12	1	29
	TOTALS	28	16	1	45

Chi square = 2.49 Level of significance .01 = 9.21

The analysis for the unknown group shows there is no difference in typing between the sweep or fixed mode.

The above analysis determined that there was a difference in typing by the sweep and fixed mode, and that the significantly discriminate area was the cochlear group. However, the above analysis still did not indicate the complete answer to the question of the experiment. That is to say, we still did not know which mode was the better indicator of the site of pathology. Therefore, a 2 X 2 table was constructed and all the tracings for the diagnostic groups were classified as to correct or incorrect based upon the medical diagnosis and the following basic assumptions for the Bekesy tracing type:

1. The correct typing for subjects whose medical diagnosis was normal, conductive or mixed, would be Type I.
2. The correct typing for subjects whose medical diagnosis was cochlear would be Type II.
3. The correct typing for subjects whose medical diagnosis was retrocochlear would be Type III.
4. The typings for the unknown category were not considered in the statistical analysis. Therefore the total N was 82.

The data were placed in a 2 X 2 table and analyzed by chi square. The results for this analysis are displayed in Table VII.

The analysis indicates that there was a statistically significant difference between the sweep and fixed modes for predicting site of pathology. The fixed frequency is a superior method for diagnosing correct site of pathology.

As can be seen from the Table, the fixed frequency identified 64 of the 82 pathologies correctly or 78%, while the sweep identified 46 pathologies or 56% correctly.

TABLE VII

SUMMARY OF CORRECT DIAGNOSIS BY FULL RANGE AND FIXED FREQUENCY BÉKÉSY TRACINGS.

		Full Range Tracings		
		Correct	Incorrect	TOTALS
Fixed Frequency Tracings	Correct	44	20	64
	Incorrect	2	16	18
	TOTALS	46	36	82

Chi square = 18.95 Level of significance .01 = 6.64

Summary.

The results indicate that for some pathologies the full range sweep tracings and the fixed frequency tracings are equally successful in predicting the site of pathology. However, for the cochlear pathologies the fixed frequency tracing is more sensitive for indicating site of pathology than the full range tracing.

Based on the statistical analysis, the null hypothesis of no difference between full range sweep frequency and fixed frequency tracings for determining site of pathology is not accepted.

EXPERIMENT 2

History.

Opinions differ as to the best method for identification of cochlear pathology from Békésy tracings. Lundborg (1952) suggested abnormally small swingwidths (1-5 decibels) showed recruitment and cochlear pathology.

Jerger (1960) concluded from his heterogeneous sample that the patterning between the interrupted and continuous tone tracings was the best method to use for identification of the various pathologies. Jerger (1962a) stated that analysis of the swingwidth proved discouraging and was not a direct test of anything. The important factor to consider was the difference or patterning between the interrupted and continuous tone thresholds.

Bilger (1965) and Bilger, Hopkinson and Richardson (1966) analyzed fixed frequency tracings at 4000 Hz and concluded that the swingwidth of the continuous tone tracing uniquely separated two populations (cochlear and noncochlear pathology).

Bilger (1965) found when he attempted to define cochlear pathology on the swingwidth of the continuous tone at 4000 Hz, a reliability coefficient of .86 was obtained. When the difference between the interrupted and continuous tones was incorporated, the coefficient dropped to .59. He concluded that a swingwidth equal to or less than 5.5 decibels was the best indicator of cochlear pathology and utilizing the difference between the interrupted and continuous tone threshold as suggested by Jerger, decreases the reliability of the classification.

The findings of Lilly (1965) also indicated that subjects with cochlear pathology will, on the average, produce Békésy tracings with a peak-to-peak amplitude (swingwidth) of less than five decibels for a continuous tone test signal.

The literature reflects a controversy as to whether the difference (D) or patterning between the interrupted and continuous tone tracings or the swingwidth (Wc) of the continuous tone is the best indication of cochlear pathology. The purpose of this experiment is to resolve that controversy.

<u>Statement of the Problem</u>.

Which parameter is the better indicator of cochlear pathology, the difference (D) or the continuous tone swingwidth (Wc)?

<u>Null Hypothesis</u>. There is no difference between the measures D and Wc in distinguishing cochlear pathology using Békésy audiometry.

<u>Procedure</u>.

Stable measures of D and Wc, obtained by fixed frequency Békésy audiometry, were used to determine which parameter is the best indicator for site of pathology. Tracings were obtained for both the pulsed and continuous tones at 500 Hz, 2000 Hz, and 4000 Hz.

Sixty-two subjects were drawn from the medical diagnostic assignment who were considered, based on the clinical literature and histopathological studies, to be good examples of cochlear pathology resulting from either acoustic trauma, head trauma and Meniere's disease. The categories of vestibular neuronitis, vascular insufficiency and arteriosclerosis were also included. In addition, those subjects whose etiology was classified otologically as "unknown," but who exhibited substantial cochlear findings on the audiological test battery were also included in the cochlear group. "Substantial cochlear findings" consisted of positive results on four of the six following tests:

1. SISI - positive if 80% or more.
2. Loudness Balance - if positive at one or more frequencies, binaural or monaural.
3. Tone Decay - positive if type II by Owen's classification.
4. Speech Discrimination - positive if 80% or less.
5. History - positive if prolonged exposure to noise.
6. Vestibular - positive on electronystagmography.

Based on the above criterion, eighteen subjects were selected out of the "unknown" group and placed into the "cochlear" group. A summary of the cochlear group is shown on Table VIII.

TABLE VIII

SUMMARY OF THE COCHLEAR GROUPING.

Menieres	18
Acoustic Trauma	12
Head Trauma	2
Viral	3
Vascular Insufficiency	6
Arteriosclerosis	3
Unknown	18
TOTAL	62

Results.

Granitz' classification system was used to type the Békésy tracings based on the difference between I and C tracings. Bilger's (1965) criterion of the swingwidth equal to or less than 5.5 dB of the continuous 4000 Hz tone was used to type the Békésy tracings based on swingwidth.

The 62 cochlear subjects were placed in a 2 X 2 table of correct-incorrect diagnosis according to typing by D and Wç. Correct were type II, cochlear pathology, and incorrect were all the other Békésy typings. The distribution of the 62 typings by D and Wc are displayed in Table IX.

As can be seen from the Table, Wc identified 32 of the total 62 cochlear pathology's correctly or 52%; and D identified 39 correctly or 62%. Fourteen cochlear pathology's, 23% were missed by both D and Wc.

TABLE IX

CLASSIFICATION OF FIXED FREQUENCY BÉKÉSY AUDIOGRAMS OF THE COCHLEAR GROUP ACCORDING TO D AND W_C.

	D		
	II	Others	TOTALS
5.5dB II	23	9	32
Others	16	14	30
TOTALS	39	23	62

$\phi = .19$ Level of confidence $.01 = 6.63$

$x^2 = 2.28$ $.05 = 3.84$

Analysis by x^2 and phi coefficient indicates that D and Wc were statistically not significantly different from each other.

However, it was still possible that an etiology subgroup of the cochlear pathology's could be identified better by D or Wc. Since the above analysis could not determine if this was a valid hypothesis, the cochlear pathology's were subdivided into the following groups. Group 1 was Meniere's, N = 18; Group 2 was acoustic trauma and head trauma, N = 14; Group 3 was viral, vascular insufficiency, and arteriosclerosis, N = 12; and Group 4 was unknown cochlear's, N = 18. The same statistical analysis that was performed on the cochlear group was done for each of the four subgroups. The classification of the typings and results are presented in Table X.

The results of the four analyses in Table X show that the specific etiologies reflect the same results as the total cochlear group. That is to say there is no subgroup which stands out as being better identified by D or Wc in the total cochlear group.

<u>Summary</u>.

Based on the statistical analysis, the null hypothesis of no difference between the measures D and Wc in distinguishing cochlear pathology is retained.

TABLE X

CLASSIFICATION BY BÉKÉSY TYPE OF FOUR GROUPS OF COCHLEAR PATHOLOGY ACCORDING TO D AND W_C.

MENIERE'S

		D: II	D: Others	TOTALS
Wc	≤ 5.5dB	7	4	11
	Others	3	4	7
	TOTALS	10	8	18

$\phi = .21$ Level of confidence $.05 = 3.84$

$X^2 = .14$

ACOUSTIC AND HEAD TRAUMA

		D: II	D: Others	TOTALS
Wc	≤5.5dB	2	2	4
	Others	6	4	10
	TOTALS	8	6	14

$\phi = .09$ Level of confidence $.05 = 3.84$

$X^2 = .07$

VIRAL, VASCULAR INSUFFICIENCY, AND ARTERIOSCLEROSIS

		D: II	D: Others	TOTALS
Wc	≤5.5dB	6	1	7
	Others	2	3	5
	TOTALS	8	4	12

$\phi = .48$ Level of confidence $.05 = 3.84$

$X^2 = 1.07$

UNKNOWN

		D: II	D: Others	TOTALS
Wc	≤5.5dB	8	2	10
	Others	5	3	8
	TOTALS	13	5	18

$\phi = .19$ Level of confidence $.05 = 3.84$

$X^2 = .09$

COROLLARY TO EXPERIMENT 2

History.

Békésy (1947) pointed out that a subject's tracing would be unusually narrow at those frequencies where recruitment was present. Reger (1952) also stated that a narrowing of the tracing is evident in the higher frequencies in subjects who have recruitment.

The most notable study that dealt primarily with the swingwidth was done by Lundborg (1952). He classified the tracings according to the swingwidth and concluded that there was a precise relationship between the swingwidth of the continuous tone tracing and recruitment.

Reger and Kos (1952) also concluded that a narrowing in swingwidth in the higher frequencies was an indication of recruitment and presumably, cochlear pathologies.

The results of Experiment 2 indicated no difference between D or Wc for identifying cochlear pathology. However, the criterion for Wc was based solely upon the absolute swingwidth of the continuous tone at 4000 Hz. The above literature suggests that utilizing the criterion of the difference of Wc from the low frequencies to the high frequencies might be a more efficient criterion to identify cochlear pathology. Therefore, it was decided to look at this aspect of Wc, the difference in Wc from a low frequency, 500, to a higher frequency, 4000 Hz, to determine if it was a more efficient measure than the absolute measure at 4000 Hz for indicating cochlear pathology.

Statement of the Problem.

The question is "Can the efficiency of the Wc measure be increased as an indicator of cochlear pathology by utilizing the difference in swingwidth at 500 Hz minus the swingwidth at 4000 Hz?"

Procedure.

The swingwidths of the tracings obtained on the cochlear group were analyzed at 500 Hz and 4000 Hz. Tracings were made over a two-minute period. The attenuation rate of the Bekesy audiometer was 2½ decibels per second. Hence the intensity range covered in one minute was 60 times 2½, or 150 decibels. The average swingwidth was obtained by counting the number of peaks and valleys in the last minute of the tracing and dividing the result into 150. For example, if there were 70 up and down excursions in the tracing, the average swingwidth was 2.14 decibels.

Results.

A summary of the swingwidths' means and standard deviations is found in Table XI.

A Students t test (Garrett, 1965) was run between the mean swing width at 500 Hz and 4000 Hz. The result (t = 8.92) was significant at .01 level of confidence,

TABLE XI

SUMMARY OF SWINGWIDTH MEANS AND STANDARD DEVIATIONS OBTAINED FROM THE VARIOUS COCHLEAR SUBGROUPS AT 500 AND 4kHz.

Group	500 Hz		4kHz		Difference
	$Mean_1$	SD	$Mean_2$	SD	$M_1 - M_2$
Meniere's	7.77	2.95	5.64	3.18	2.13
Acoustic Trauma and Head Trauma	8.28	2.64	6.64	3.02	1.64
Viral, Vascular Insufficiency and Arteriosclerosis	7.17	3.09	5.25	3.20	1.92
Unknown Cochlears	8.08	2.68	4.81	2.30	3.27
Overall Cochlear	7.86	1.92	5.55	2.52	2.31

indicating that there is a statistically significant difference between the means of the two frequencies.

A Sign test (Garrett, 1965) was run on the differences between 500 Hz and 4000 Hz for each subject. The result of 5.84 was significant at the .01 level of confidence, again indicating that there is a significant difference between the two frequencies.

A coefficient of correlation (r) (Garrett, 1965) calculated from the raw data was also significant (.60) at the .01 level of confidence.

Summary.

The results indicate that the swingwidth is significantly smaller at 4000 Hz in comparison to 500 Hz. Utilizing the difference in Wc at 500 Hz minus 4000 Hz is a more efficient measure than the absolute value of Wc at 4000 Hz in identifying cochlear pathology. The question of statistical significance versus clinical application will be taken up in the discussion section.

EXPERIMENT 3

History.

In conventional Békésy audiometry, the full range threshold tracings are made with the frequency changing from a low frequency, usually 100 Hz or 200 Hz, to a high frequency, 6000 Hz or 8000 Hz. This is labeled a forward full range sweep frequency Békésy tracing, conventionally referred to as forward sweep tracing. When the direction of frequency change is from a high frequency to a low frequency, this is labeled a reverse full range sweep frequency Békésy tracing, conventionally referred to as a reverse sweep tracing.

Corso and Wilson (1957) were the first to study the effect of a reverse sweep tracing on threshold. They reported that thresholds for the high frequencies were more sensitive on the forward sweep tracing and more sensitive in the low frequencies on the reverse sweep tracing, with the two curves crossing at 750 Hz. Their conclusion was that more sensitive thresholds are obtained toward the end of a given test.

Epstein (1960) administered forward and reverse sweep tracings over the 2000-4000 Hz octave range and found in every instance the variability or trace width around threshold was less overall except at 3000 Hz for the reverse tracings.

Harbert and Young (1962) found the thresholds superimposed on the forward and reverse tracings up to

1500 Hz, but from 1500 to 8000 Hz, the thresholds were distinctly more sensitive on the reverse tracings.

Rose (1962) found that the direction of sweep affected both the threshold values and the variability around threshold. In many cases the reverse sweep tracings showed a separation that had not appeared in the forward sweep tracing and thresholds on the reverse sweep tracings were less sensitive (poorer) than those obtained on the forward sweep tracing. These results are contrary to those of Corso and Wilson (1957), Epstein (1960), and Harbert and Young (1962).

The data of Rose may have been confounded because he changed the speed of frequency traverse and attenuation rate by half during the reverse continuous tone sweep tracing only. Corso and Wilson (1957) stated that the speed of frequency change and attenuation rate must be kept constant throughout the test if valid thresholds are to be obtained.

Palva, Karja and Palva (1970) obtained essentially the same results in normal subjects as did Corso and Wilson (1957), i.e., more sensitive thresholds are obtained toward the end of the test. They also found overlap of the forward and reverse sweep tracings in 90% of the 231 ears with sensorineural hearing impairment. The remaining 10% always showed poorer or less sensitive thresholds in the reverse sweep tracing.

Statement of the Problem.

This study was designed to determine if the reversed full range continuous tone sweep frequency Békésy tracing provides test results that are more easily and more reliably classified by Granitz' classification of Békésy tracings.

Null Hypothesis. There is no difference in the amount of separation between the forward interrupted and continuous tone sweep tracings and the forward interrupted-reversed continuous tone sweep tracings.

Procedure.

Reverse continuous tone sweep frequency tracings were obtained on 38 subjects drawn at random from the 127 subjects used as the sample for this paper. Of the 38 subjects, 30 had otovestibular complaints and 8 were normal hearing subjects with no otovestibular complaints. The 30 pathological subjects were administered a reverse full range sweep frequency Békésy test, in addition to the complete audiological diagnostic test battery. The 8 normal subjects were administered only the Békésy test sequence. The tracings consisted of a full range forward interrupted and continuous tone sweep frequency tracing, a full range reversed continuous tone sweep frequency tracing and fixed frequency interrupted and continuous tone tracing at 500, 2000, and 4000 Hz.

Presentation of the direction of sweep frequency tracings (forward or reversed) were counterbalanced between subjects. For example, subject number one was presented the continuous tone in the forward direction first. Subject number two was presented the continuous tone in the reverse direction first, and so on. All tracings were made with the attenuation rate set at 2.5 decibels per second. Total time to sweep from 150 to 8000 Hz was 6 2/3 minutes. The pulsed tone was interrupted 2½ times each second.

Results.

The tracings obtained from the normals showed no differences in thresholds by either method, indicating that the test method appeared to be a valid procedure to test for the pathologicals. The data for the normals are not included in the following results.

The comparison of typing based upon forward and reversed sweep frequency tracings of the thirty subjects is shown in Table XII. A chi square of 12.00 was not significant at the .01 level of confidence, indicating no significant difference in the obtained results by forward and reverse tracings.

Summary.

The above findings do not agree with those of Rose (1962). In all probability changing the speed and attenuation rate during the reverse tracing confounded his results. The findings of others (Corso and Wilson, 1957;

TABLE XII

COMPARISON OF CLASSIFICATION BASED UPON FORWARD AND REVERSED FULL RANGE SWEEP FREQUENCY BÉKÉSY TRACINGS.

		Classification of Forward Full Range Sweep Tracings				
		I	II	III	IV	TOTALS
Classification of	I	6	3			9
Reverse Full Range	II	7	7			14
Sweep Tracings	III					
	IV	3	1		3	7
	TOTALS	16	11		3	30

$X^2 = 12.00$ Level of significance for .01 = 13.28

Epstein, 1960; and Harbert and Young, 1962) were also not evident in the tracings obtained for this study. There were no crossings of thresholds in the forward and reverse tracings to indicate improved sensitivity toward the end of the test.

Possibly the two variables contributing to the lack of agreement between this and other studies were the instructions and training the subjects received. Requiring the subjects to meet a strict criterion of swingwidth apparently influences the results, since the only other major difference between all studies was the subjects.

Based on the results of this study, it can be stated that thresholds obtained on clinical subjects will be the same on sweep frequency tracings regardless of the direction of frequency change.

The null hypothesis of no difference in the amount of separation between the forward interrupted and continuous tone sweep tracings and the forward interrupted-reversed continuous tone sweep tracings is retained.

EXPERIMENT 4

History.

Initially, diagnostic information was obtained from a Békésy audiogram by looking at the amplitude or swingwidth of the continuous tone tracing.

In 1960, Jerger compared the interrupted and continuous tone tracings and demonstrated that the differences in absolute thresholds of the two tracings also contained diagnostic information. He attempted to analyze the tracings quantitatively using such indices as the amplitude of the continuous tone tracing, the number of threshold crossings per quarter octave, the difference between tracing width at high and low frequencies, the difference between the continuous and interrupted tone tracing widths, and the difference between the continuous and interrupted tone midpoints.

He found the results of quantitative analysis "exceedingly discouraging (p. 278)." On the other hand, he felt that a qualitative judgement of the patterning or relationship between the continuous and the interrupted tone tracings had important diagnostic value. The tracings were simply analyzed by visual inspection of the patterning between the continuous and interrupted tones.

Békésy audiometry is currently used as one of a battery of special tests for diagnostic audiology (Jerger, 1962a). The major consideration for predicting site of lesion is the pattern of agreement among the many tests. When the results of Békésy audiometry do not fit or agree with the other test results, they are disregarded for diagnostic value.

Due to the many attractive inherent features of Békésy audiometry, experts foresee the Békésy audiometer becoming the standard audiometric tool in clinical audiology. It has even been suggested that the Békésy audiometer will make the manual audiometer obsolete as a diagnostic instrument (Hirsh, 1962; Jerger, 1962a).

For this to occur, Békésy audiometry must be critically examined for its ability to stand alone as a diagnostic test. One important aspect to examine is the underlying foundation for the typing of Békésy audiograms for diagnostic value. The importance of determining whether the analysis of Békésy tracings is an art, as Jerger suggests, or skill is critical for the future development and refinement of clinical audiology.

"Art" is defined as being a qualitative judgement based on a visual inspection of the relation between the continuous and interrupted tone tracings made by a sophisticated judge. This is a subjective judgement.

"Skill" is defined as being a quantitative method of analysis for typing the tracings. This is an objective measure.

Utilization of an art form (qualitative method) to analyze poses the question of how much training and sophistication does an individual need to interpret Békésy tracings? It also seems to imply that beginning audiologists are not competent or sophisticated enough to analyze the tracings.

If analysis of Békésy audiograms can be quantified, then its utility will be increased. It would also resolve the problem of clinical competence of the clinical audiologist.

Statement of the Problem.

Is Békésy typing an art or skill? Is there any difference between Békésy typing by clinical experts using visual inspection of patterns, utilizing clinical experience and clinical intuition, and Granitz' numerical classification?

Null Hypothesis. There is no difference between the typing of Békésy tracings by visual inspection by a group of expert clinical audiologists and the numerical typing by Granitz.

Procedure.

Four judges were selected who were considered experts in the field of audiology. An expert was defined as an audiologist who met the following criteria:

1. Awarded the Certificate of Clinical Competence in Audiology from the American Speech and Hearing Association.
2. Had a minimum of ten years of experience as a clinical audiologist.
3. Was currently working in a clinical setting.
4. Had published articles pertaining to Békésy audiometry.

The judges were asked to type 170 Békésy tracings. There were 47 right ear sweep frequency tracings, 47 right ear fixed frequency tracings, 38 left ear sweep frequency tracings, and 38 left ear fixed frequency tracings. They were separated into four groups: right sweep, right fixed, left sweep, and left fixed. Included for each subject was a full range sweep tracing and the fixed frequency tracing for the particular ear included in the sweep tracing group.

The judges typed the audiograms blind with the one restriction that all tracings had to go into one of four types. They were also asked to use their clinical judgement and experience, such that their typing would be congruent with the total audiometric battery.

Results.

To analyze the art-form, a contingency coefficient (C) (Garrett, 1965) was run for each judge against an objective criterion, Granitz' numerical system. Table XIII shows, in addition to the obtained C values, a second set of C values which was computed to correct for grouping. Correcting C

TABLE XIII

NUMBER OF DIFFERENCES BETWEEN JUDGES' AND GRANITZ' CLASSIFICATION OF BÉKÉSY AUDIOGRAMS.

Judge	Number of Differences	C	C (Corrected)	x^2
1	36	.81	.94	324.33
2	56	.77	.89	289.34
3	21	.80	.92	302.22
4	49	.75	.86	218.57
N = 170			9df, x^2 .01 = 21.67	

for the number of groups provides a clearer indication of the high degree of relationship between the ratings, as the maximum C obtainable for a 4 X 4 table is .866 (Garrett, 1965).

As seen in Table XIII, the qualitative method of typing by the judges agreed significantly with the quantitative method adopted by Granitz. This suggests the validity of the art form by the high degree of agreement between a subjective criterion and an objective criterion for analyzing Békésy tracings.

Since the judges showed excellent agreement against an objective criterion, it was decided to determine how well the judges agreed with each other. In addition to showing the inter-judge correlation, it also pointed out two other areas of interest - the areas of agreement and disagreement between judges in regard to typing Békésy audiograms.

Table XIV shows that agreement between judges was also highly significant.

TABLE XIV

NUMBER OF DIFFERENCES BETWEEN JUDGES' CLASSIFICATIONS OF BÉKÉSY AUDIOGRAMS.

Judges	Number of Differences	C	C (Corrected)	x^2
1 & 2	40	.77	.89	289.34
1 & 3	36	.78	.90	264.11
1 & 4	29	.78	.90	264.11
2 & 3	54	.77	.89	289.34
2 & 4	37	.78	.90	264.11
3 & 4	43	.77	.89	289.34
N = 170			9df, x^2 .01 = 21.67	

A complete summary of the Békésy typings by the judges and Granitz is found in Table XV. Plotting shows areas of agreement and disagreement between judges and Granitz, and judges and judges. The upper right half of the table shows the corresponding C and corrected C values.

For example, to find how the typing of judge 1 compared with Granitz, start with Granitz in the abscissa and drop down to judge 1, on the ordinate. The figures show that both labeled the same 70 tracings as type I, 50 were jointly labeled as type II, 9, were type III, and 5 were type IV. There were 31 tracings typed as I by Granitz and typed as II by judge 1, and so on. The single row of

TABLE XV

SUMMARY OF TYPING 170 BÉKÉSY AUDIOGRAMS BETWEEN: (1) JUDGES AND GRANITZ, (2) JUDGES AND JUDGES. PLOTTING BY N, C, AND CORRECTED (C).

		Granitz				Judge 1				Judge 2				Judge 3				Judge 4			
		I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
Granitz	I	102																			
	II		54			C = .81 (.94)				C = .76 (.89)				C = .80 (.92)				C = .75 (.86			
	III			9																	
	IV				5																
Judge 1	I	70	1			71															
	II	31	50				81			C = .77 (.89)				C = .78 (.90)				C = .78 (.90)			
	III			9				9													
	IV	1	3		5				9												
Judge 2	I	59				52	7			59											
	II	41	42		1	18	63		3		74			C = .77 (.89)				C = .78 (.90)			
	III			9				9				9									
	IV	2	12		4	1	11		6				18								
Judge 3	I	92	7			70	27		2	59	37		3	99							
	II	10	47		4	1	54		6		47		14		61			C = .77 (.89)			
	III			9				9				9				9					
	IV				1				1				1				1				
Judge 4	I	62	1			57	5		1	50	13			62	1			63			
	II	40	49		3	14	73		5	9	70		13	36	56				92		
	III			8				8				8				8				8	
	IV		4	1	2		3	1	3			1	5	1	4	1	1				7

numbers appearing in the diagonal are the total number of each type by each judge. For example, judge 3 labeled 99 tracings as type I, 61 as type II, 9 as type III and 1 as type IV. As stated earlier the correlations are shown in the upper right half and can be obtained by crossing a line vertically and horizontally from the ordinate and abscissa for the desired information. To find the C and corrected C values between judge 3 and judge 4, drop down from judge 4 on the abscissa until you are across from judge 3 on the ordinate. The C is .77 and the corrected C is .89.

Summary.

The results of Experiment 4 indicate no significant difference between a numerical system of typing and the typing by expert judges of Békésy tracings.

The null hypothesis of no difference between the typing of Békésy tracings by visual inspection by a group of expert clinical audiologists and the numerical typing by Granitz is retained.

CHAPTER VI

DISCUSSION

Békésy audiometry is a major special diagnostic procedure in clinical audiology. This investigation evaluated the diagnostic significance of the interpretation of Békésy audiograms.

The audiologists' concern is the determination of site of pathology. The physician makes the diagnosis of etiology and in most cases etiology is associated with site of pathology. This relationship points out a basic assumption underlying this investigation: The medical diagnosis was used as the criterion for measuring the effectiveness of Békésy audiometry in pointing out the site of lesion.

The variable of swingwidth was investigated initially, as it seemed reasonable to assume that Bekesy audiometry could be improved as a clinical tool if subjects were trained to meet a specific criterion. It was found that subjects could meet and maintain a strict ±5 decibel swingwidth criteria. Subject training took no longer than the standard instructions. It was found that analogies, along with positive or negative reinforcement throughout the test session worked best in meeting and maintaining the criterion.

This finding casts doubt upon Epstein's (1960) statement that there are narrow and wide swingers in the clinical population. If one recognizes the fact that a clinical population can be trained to meet a strict swingwidth criterion with very little difficulty, then the results of studies (Epstein, 1960; Grayson, 1967; Harbert and Young, 1966; Muma and Siegenthaler, 1966; Siegenthaler, 1961; Stark, 1965) reporting data based on swingwidth extending to as much as 30 decibels must be looked on with some apprehension.

The most plausible explanation for the great variability in their data is that after the instructions were given, the subjects were left to determine their thresholds based on their own internal criterion, rather than being made to meet a strict criterion around what the investigator knew to be the range of threshold. Numerous subjects in this study had the same variability initially, but were easily trained to the ±5 decibel swingwidth. This finding makes the validity of those conclusions based on swingwidth regarding typing or etiology suspect.

Because Békésy audiometry is usually administered either in the full range or fixed frequency mode, an attempt was made to determine which testing procedure was the better indicator of site of pathology. The obtained results for the normal, conductive and retrocochlear groups show no difference between the two test modes.

The results for the mixed, cochlear, and unknown groups showed no significant difference between the two test modes even though differences did exist. For example in the cochlear group, the fixed frequency tracings showed more type II's than did the full range sweep tracings. One explanation for this result is that during the sweep tracing any difference between the interrupted and continuous tone threshold is being masked out by the time factor. On the sweep tracing, frequency is moving by time. At any particular moment in time, the frequency is changing requiring the subject to do two things:

1. Trace threshold by intensity.
2. Search for frequency as it is always changing.

Because this masking problem is inherent in the full range sweep tracing, fixed frequency is the preferred method to use in testing.

The data indicate that Békésy audiometry is improved as a clinical tool for pointing out site of pathology if fixed frequency tracings are obtained and separation is present between the interrupted and continuous tone thresholds in the higher frequencies.

An attempt was then made to resolve the controversy of which parameter, the difference between the interrupted and continuous tone tracings or the swingwidth of the continuous tone, is the better indicator of cochlear pathology. The evaluation of D and Wc shows no difference between these two methods for identifying cochlear pathology. The medical diagnosis was used to form subgroups within the cochlear group in an attempt to see if D and Wc would identify a specific etiology. The results show that no subgroups are identified better by D or Wc. At best, D only identified 62% of the cases, while Wc only identified 52%.

The attempt to see if Wc could be improved as a clinical tool by looking at the difference in Wc between 4000 Hz and 500 Hz, showed that a statistically significant difference exists between the swingwidth of the two frequencies. Békésy (1947) and Lundborg (1952) both report that narrowing of the tracing in the higher frequencies is a good indicator of cochlear pathology. The swingwidths between 500 Hz and 4000 Hz are statistically different, but the difference is of no practical use clinically, because it is so small. The reason it cannot work clinically is the difference is based on a group average and not on individual tests. For group data, the D is small but highly significant. Application of this finding to one subject would be useful if that subject were run numerous times to develop a body of data to see if the D is consistant. However, it is impracticable in a clinical situation because of the time involved to determine if the small difference is reliable for an individual. On a research basis, or in a psychoacoustic experiment, one would have to say that Békésy (147) and Lundborg (1952) were right, but for clinical applications a difference of 2.5 decibels between 4000 Hz and 500 Hz is questionable as a diagnostic tool.

The determination of whether the analysis of Békésy audiograms is an art or skill is one of the major outcomes of this investigation. It was observed that expert judges using a qualitative method for typing Békésy tracings were in excellent agreement with the quantitative method of Granitz. Interjudge agreement was also excellent.

This finding points out that judges, either consciously or unconsciously, use a quantifiable method of analysis. In other words, they are using, whether they are aware of it or not, a subjective judgement that can be translated to a quantifiable number. It is also interesting to note that while they are doing this, they reported that they did not want or like to categorize some of the Békésy tracings. They questioned some of the tracings as to type and typed them only because they were forced to put them into a category. It suggests that had they not been forced, they would not have categorized them until they had other audiological information. It is possible that what they would have done was then type the tracing to be congruent with the other information, even though the Bekesy tracing, in and of itself, was questionable as to type.

The interjudge agreement indicates that each judge uses a criterion for typing Békésy audiograms that is related to the criteria used by each of the other judges. This is important as it shows that each method of typing is quantifiable. A quantifiable method of analysis means that test results can be exchanged across the country. Massive amounts of data can be accumulated in central areas for further research. It also means that the training and teaching of Bekesy audiometry to new clinicians can now be simplified, because they no longer have to learn a clinical skill first, but can rely on an objective measure.

It would appear the major problem in Békésy typing centers on cochlear pathology and type II. Types I and III are well established for normal, conductive and retrocochlear subjects. Type IV's constitute a small portion of the tracings in this study, therefore a definite statement cannot be made as to their diagnostic significance.

Identification of cochlear pathology by either D or Wc, as they are now used, is not very efficient. In this study the D and Wc correctly identified cochlear pathology 62 and 52% of the time respectively. One possible solution for improving the identification rate was tried by using a D of 5 decibels at 2000 Hz or 4000 Hz. When this was done the rate of identification by full range sweep tracings improved from 56 to 73%. Identification by fixed frequency only improved from 78 to 79%. Only the efficiency of the full range sweep tracing was improved by this modification of D.

Possibly, changing the signal parameters will improve even further the validity of Békésy audiometry. Jerger and Jerger (1966) have shown that subjects with audiological evidence of eighth nerve pathology demonstrated an abrupt loss of acuity for interrupted tones when the silent interval or off time between successive 200 millisecond tones fell below 100 milliseconds. The abrupt loss did not occur when the signal parameters available in the standard Bekesy audiometer were utilized. Dallos and Tillman (1966) found that stimulus duration does not radically affect threshold values, but off times below 50 milliseconds will. Wright (1968a; 1968b) found that less variability is seen between Békésy tracings for the interrupted tone from subjects having sensorineural hearing impairments when the duration of the signal is progressively shortened from 500 milliseconds. In a later article, Wright (1969) found that the difference between the interrupted and continuous tones became much greater and clinically significant when the interrupted signal was presented one time per second (500 milliseconds on, 500 milliseconds off).

Palva et al. (1970) have investigated the reverse continuous tone tracings and stated that unusual reverse tracings may be an indication of a central lesion. Their statement is based on the fact that several subjects having confirmed central lesions had unusual reverse tracings.

These new and different attempts to improve Békésy audiometry as a diagnostic tool suggest that what we must look for is not more tests, but ways to make our present tests better and more efficient. At the present time Békésy audiometry appears to have the most potential for accomplishing this goal.

This investigation has shown that subjects can be trained and the results can be quantified. Possibly these two factors combined with the research of others will prove beneficial.

The results of this investigation suggest the possibility of Békésy audiometry being sufficient as the diagnostic battery. The interrupted tone threshold can be used for auditory sensitivity and the continuous tone can be used for the identification of pathology. Bone conduction tests can be administered with a Bekesy audiometer as well as speech reception thresholds (Lezak, Siegenthaler and David, 1964). Utilization of the Békésy audiometer in this manner would reduce testing time without sacrificing the reliability of the standard audiometric test battery.

Békésy audiometry provides threshold information not obtainable by standard audiometric techniques. The subject tests himself thereby eliminating any of the tester's bias or influence. With the standardization of the instructions and the establishment of a swingwidth criterion, the test can be administered by subprofessionals to a clinical population, or be utilized in mass testing services by industry, the military, or any large group, with a great deal of reliability.

Its potential becomes unlimited if one considers its value as a screening diagnostic tool in physicians' offices where the subprofessional or audiometric technician is more readily available.

The establishment of a standardized quantifiable method of administration and analysis would create an unlimited potential for Békésy audiometry in audiological diagnosis.

CHAPTER VII

SUMMARY AND CONCLUSIONS

Békésy audiometry was not seriously considered as a clinical tool until Jerger (1960) introduced his four types or patterns of tracings. Typing was based on the difference between the interrupted and continuous tone thresholds obtained during a full range sweep frequency tracing. Normals and middle ear lesions were predominantly type I, cochlear lesions were predominantly type II, and eighth nerve lesions were predominantly types III and IV.

Bilger (1965), Bilger, Hopkinson and Richardson (1966), and others, contended that the swingwidth of the continuous tone during fixed frequency tracings is a better method for predicting the site of lesion.

This investigation evaluated the diagnostic value of various methods used to interpret Békésy audiograms.

Prior to the experiments a pilot study on swingwidth showed that typical clinic population could meet and maintain a strict swingwidth criterion of ±5 decibels. The pilot study demonstrated that a baseline could be established which allowed a meaningful comparison and analysis of the results to be made.

The first experiment compared full range sweep frequency and fixed frequency tracings to determine which was the better indicator of site of pathology. Békésy tracings from 127 subjects were analyzed utilizing a numerical system of typing proposed by the writer. The validating criterion for site of pathology was the medical diagnosis. The results indicated that for subjects with normal hearing, conductive hearing impairments and those with retrocochlear lesions, the full range sweep frequency tracings and the fixed frequency tracings are equally successful in predicting the site of pathology. For those subjects with cochlear pathologies, the fixed frequency tracings are more sensitive for indicating site of pathology.

The second experiment, extending the findings of the first experiment, compared the difference (D) between the interrupted and continuous tone tracings and the width of the continuous tone tracing (Wc) to determine which was the better indicator of cochlear pathology. Sixty-two subjects were used who were considered to be good examples of cochlear pathology. Fixed frequency tracings were obtained at 500, 2000, and 4000 Hz, for the interrupted and continuous tones over a two minute period. The results indicated that there is no difference between the measures D and Wc in distinguishing cochlear pathology.

A corollary to Experiment 2 was run in which the Wc at 4000 Hz was compared to the Wc at 500 Hz, to determine if the efficiency of Wc could be increased. The bases for the corollary study were results of Experiment 1 and earlier studies which indicated that the continuous tone narrowed in the higher frequencies with cochlear pathologies. The results of the analysis indicate that Wc at 4000 Hz was significantly narrower than at 500 Hz.

The third experiment compared the amount of separation between the full range forward interrupted and continuous tone sweep tracings. Thirty subjects were used in the experiment. The results indicate that normal subjects' thresholds will be the same regardless of the direction of frequency change. Subjects with otovestibular complaints will show some difference but the difference was not consistent nor great enough to facilitate typing Békésy audiograms.

The fourth experiment compared the qualitative method of typing Békésy audiograms with the quantitative method proposed by the writer. One hundred and seventy tracings were typed by four judges and the results of their typing were compared to the quantitative or numerical method of Granitz. The results indicate no difference between the judges' and Granitz' method. There was also no significant difference between judges. In essence, both methods of typing accomplish the same thing.

In conclusion, the results of this study show that Békésy audiometry is a good clinical tool. The efficiency of predicting the site of lesion by the typing of Békésy audiograms of etiological groups varies from excellent for the majority to only fair for the cochlear pathologies. While fixed frequency typing is superior to the sweep mode for diagnostic value, it still misses an unwarranted number of cochlear pathologies.

A major finding of this study is the fact that typing is amenable to numerical quantification. This moves Békésy audiometry from the realm of clinician expertise and subjective evaluation to the domain of clinical science and objective measurement. The need and direction of future research in clinical Békésy audiometry is the quantifiable evaluation of the variables utilized in Békésy audiometry, particularly the signal ensemble. This will result in improvement in current methods of typing and/or new methods of typing classification.

This study supports the prediction of previous researchers that Békésy audiometry has the potential to stand alone as a diagnostic tool in clinical audiology.

BIBLIOGRAPHY

BIBLIOGRAPHY

Bangs, J. L., and Mullins, C. J., Recruitment testing in hearing and its implications. Arch. Otolaryngol., 58, 582-592 (1953).

Békésy, G. v., A new audiometer. Acta oto-laryngol., 35, 411-422 (1947).

Békésy, G. v., Experiments in Hearing. New York: McGraw-Hill Book Co., Inc. (1960).

Bilger, R., Some parameters of fixed-frequency Békésy audiometry. J. speech hear. Res., 8, 85-95 (1965).

Bilger, R., Hopkinson, N. T., and Richardson, J. B., Detection of cochlear overlay by full-range and discrete frequency Békésy audiometry. Laryngoscope, 76, 1533 (1966).

Bradford, L. J., and Goetzinger, C. P., A study of the order effects on tracings made with a Békésy-type audiometer. Acta oto-laryngol., 58, 17-31 (1964).

Burns, W., and Hinchcliffe, R., Comparison of the auditory threshold as measured by individual pure tones and by Békésy audiometry. J. acoust. Soc. Amer., 29, 1274-1277 (1957).

Byers, V. W., Two methods of measuring recovery following short-duration fatigue. J. acoust. Soc. Amer., 35, 662-671 (1963).

Carhart, R., and Jerger, J. F., Preferred method for clinical determination of pure-tone thresholds. _J. speech hear. Dis._, 24, 330-345 (1959).

Corso, J., Evaluation of operating conditions on a Békésy-type audiometer. _Arch. Otolaryngol._, 61, 649-653 (1955).

Corso, J., Effects of testing methods on hearing thresholds. _Arch. Otolaryngol._, 63, 78-91 (1956).

Corso, J., and Wilson, J., Additional variables on the Békésy-type audiometer. _Arch. Otolaryngol._, 66, 719-728 (1957).

Dallos, P., and Tillman, T., The effects of parameter variations in Békésy audiometry in a patient with acoustic neurinoma. _J. speech hear. Res._, 9, 557-572 (1966).

Dix, M. R., Hallpike, C. S., and Hood, J. D., Observations upon the recruitment phenomenon with special reference to the differential diagnosis of disorders of the internal ear and VIII nerve. _Proc. Roy. Soc. Med._, 41, 516-526 (1948).

Dix, M. R., and Hood, J. D., Modern developments in pure tone audiometry and their application to the diagnosis of end organ deafness. _Proc. Roy. Soc. Med._, 46, 992 (1953).

Elpern, B. S., The relative stability of half-list and full-list discrimination tests. _Laryngoscope_, 71, 30-36 (1961).

Epstein, A., Variables involved in automatic audiometry. Ann. Otol. Rhinol. Laryngol., 69, 137-141 (1960).

Fowler, E., Marked deafened areas in normal ears. Arch. Otolaryngol., 8, 151-155 (1928). Cited by H. Newby, Audiology: Principles and Practices. New York: Appleton-Century Crofts, Inc. (1958).

Garrett, H., Statistics in Psychology and Education. New York: David McKay Co., Inc. (1965).

Grason-Stadler Company, Inc., Audiology, Psychoacoustics, Manual for Békésy Audiometer Model E 800. (1963a).

Grason-Stadler Company, Inc., Instruction Manual for Békésy Audiometer Model E 800. 50/1062, E800-zl, Rev. 1 (1963b).

Grason-Stadler Company, Inc., Specification Sheet on Békésy Audiometer Model E 800. 5m/463 (1963c).

Grayson, B., The effect of direction of frequency traverse in automatic audiometry in evaluating sensorineural hearing losses. Unpublished M.S. thesis, Tulane University (1967).

Harbert, F., and Young, I., Threshold auditory adaptation. J. aud. Res., 2, 229-246 (1962).

Harbert, F., and Young, I., Threshold auditory adaptation measured by tone decay test and Békésy audiometry. Ann. Otol. Rhinol. Laryngol., 73, 48-60 (1964).

Harbert, F., and Young, I., Amplitude of Békésy tracings with different attenuation rates. _J. acoust. Soc. Amer._, 39, 914-919 (1966).

Harbert, F., and Young, I., Audiologic findings in Ramsay Hunt syndrome. _Arch. Otolaryngol._, 85, 632-639 (1967).

Harris, J. D., Békésy audiometry at 20 frequencies from 0.2 to 6 kc. _J. acoust. Soc. Amer._, 36, 1954-1955 (1964).

Hirsh, I., _The Measurement of Hearing_. New York: McGraw-Hill Book Company, Inc. (1952).

Hirsh, I., Békésy's audiometer. _J. acoust. Soc. Amer._, 34, 1333-1336 (1962).

Hirsh, I., Davis, H., Silverman, S., Reynolds, E., Eldert, E., and Benson, R., Development of materials for speech audiometry. _J. speech hear. Dis._, 17, 321-337 (1952).

Hirsh, I., Palva, T., and Goodman, A., Difference limen and recruitment. _Arch. Otolaryngol._, 60, 525-540 (1954).

Hirsh, I., and Bilger, R., Auditory-threshold recovery after exposures to pure tones. _J. acoust. Soc. Amer._, 27, 1186-1194 (1955).

Hood, W., Campbell, R., and Hutton, C., An evaluation of the Békésy ascending descending gap. _J. speech hear. Res._, 7, 123-132 (1964).

Hopkinson, N., Significance of type IV Békésy audiograms. Paper presented at 1965 Convention of the American

Speech and Hearing Association in Chicago.

Hopkinson, N., Modifications of the four types of Békésy audiograms. J. speech hear. Dis., 31, 79-82 (1966).

Hudgins, C., Hawkins, J., Karlin, J., and Stevens, S., The development of recorded auditory tests for measuring hearing loss for speech. Laryngoscope, 57, 57-89 (1947).

Jerger, J., Békésy audiometry in analysis of auditory disorders. J. speech hear. Res., 3, 275-287 (1960).

Jerger, J., Békésy audiometry. Int. audiol., 1, 160-164 (1962a).

Jerger, J., Comparative evaluation of some auditory measures. J. speech hear. Res., 5, 3-17 (1962b).

Jerger, J., Békésy audiometry - a misunderstanding. J. speech hear. Dis., 30, 302 (1965).

Jerger, J., Shedd, J., and Harford, E., On the detection of extremely small changes in sound intensity. Arch. Otolaryngol., 69, 200-211 (1959).

Jerger, J., and Jerger, S., Critical off-time in VIIIth nerve disorders. J. speech hear Res., 9, 573-583 (1966).

Landes, B., Recruitment measured by automatic audiometry. Ann. Otol. Rhinol. Laryngol., 68, 649-653 (1958).

LeZak, R., Siegenthaler, B., and David, A., Békésy-type audiometry for SRT. J. aud. Res., 4, 181-189 (1964).

Lierle, D., and Reger, S., Further studies of threshold shifts as measured with the Békésy-type audiometer. Ann. Otol. Rhinol. Laryngol. 63, 772-784 (1954).

Lilly, D., The effects of rate of attenuation and mode of signal presentation upon the amplitude of the Békésy envelope. Paper presented at 1965 Convention of the American Speech and Hearing Association in Chicago.

Lundborg, T., Diagnostic problems concerning acoustic tumors. Acta oto-laryngol., Supplement 99, 73-110 (1952).

Muma, J., and Siegenthaler, B., Békésy excursion size for Normal-hearing young adults. J. aud. Res., 6, 289-296 (1966).

Owens, E., Békésy tracings and site of lesions. J. speech hear. Dis., 29, 456-468 (1964a).

Owens, E., Tone-decay in VIIIth nerve and cochlear lesions. J. speech hear. Dis., 29, 14-22 (1964b).

Owens, E., Békésy tracings, tone decay, and loudness recruitment. J. speech hear. Dis., 30, 50-57 (1965).

Palva, T., Absolute thresholds for continuous and interrupted pure tones. Acta oto-laryngol., 46, 129-136 (1956a).

Palva, T., Recruitment tests at low sensation levels. Laryngoscope, 66, 1519-1540 (1956b).

Palva, T., Recruitment testing. Arch. Otolaryngol., 66, 93-98 (1957a).

Palva, T., Self-recording threshold audiometry and recruitment. Arch. Otolaryngol., 65, 691-702 (1957b).

Palva, T., Karja, J., and Palva, A., Forward vs. reversed Békésy tracings. Arch. Otolaryngol., 91, 449-452 (1970).

Pestalozza, G., and Cioce, C., Measuring auditory adaptation. The value of different clinical tests. Laryngoscope, 72, 240-251 (1962).

Price, L., Threshold testing with Békésy audiometer. J. speech hear. Res., 6, 129-133 (1963).

Reger, S., Differences in loudness response of the normal and hear-of-hearing ear at intensity levels slightly above threshold. Ann. Otol. Rhinol. Laryngol., 45, 1029-1039 (1936). Cited by H. Newby, Audiology: Principles and Practices. New York: Appleton-Century Crofts, Inc. (1958).

Reger, S., A clinical and research version of the Békésy audiometer. Laryngoscope, 62, 1333-1351 (1952).

Reger, S., and Kos, C., Clinical measurements and implications of recruitment. Ann. Otol. Rhinol. Laryngol., 61, 810-823 (1952).

Resnick, D. M., Reliability of the twenty-five word phonetically balanced lists. J. aud. Res., 2, 5-12 (1962).

Rodda, M., Bekesy tracing. Ann. Otol. Rhinol. Laryngol., 73, 222-237 (1964).

Rose, D., Some effects and case histories of reversed frequency sweep in Békésy audiometry. J. aud. Res., 2, 267-278 (1962).

Rudmose, W., Automatic audiometry. Cited by J. Jerger (Editor), _Modern Developments in Audiology_. Chapter 2. New York: The Academic Press (1963).

Siegenthaler, B., Reaction time, difference limen and amplitude of excursion on normal Békésy audiometry. _J. aud. Res._, 1, 285-293 (1961).

Sorensen, H., Clinical application of continuous threshold recordings. _Acta oto-laryngol._, 54. 403-422 (1962).

Stark, E. W., Békésy audiometry with normal-hearing and hearing impaired children. _J. aud. Res._, 5, 73-83 (1965).

Stevens, S., Mathmatics, measurements, and psychophysics. Cited by S. Stevens (Editor), _Handbook of Experimental Psychology_. Chapter 1. New York: John Wiley and Sons, Inc. (1963).

Susuki, T., and Kubota, K., Normal width in tracing on Békésy audiograms. _J. aud. Res._, 6, 91-96 (1966).

Tobias, J., On phonemic analysis of speech discrimination tests. _J. Speech hear. Res._, 7, 98-100 (1964).

Watson, J., and Voots, R., A report on the use of the Békésy audiometer in the performance of the Stenger test. _J. speech hear. Dis._, 29, 36-46 (1964).

Wright, H., Clinical measurement of temporal auditory summation. _J. speech hear. Res._, 11, 109-127 (1968a).

Wright, H., The effect of sensori-neural hearing loss on threshold-duration functions. *J. speech hear. Res.*, 11, 842-852 (1968b).

Wright, H., Békésy audiometry and temporal summation. *J. speech hear. Res.*, 12, 865-874 (1969).

APPENDIX

APPENDIX A

A Study of Békésy Swingwidth According to Criterial Measures

A. History.

A neglected variable in the review of Békésy audiometry pertained to the instructions to the subject and his introduction to the task. This neglect can be traced back to Békésy's (1947) original article introducing his audiometer. He did not mention specific instructions other than the fact that the subject was told to press the switch when he did not hear the tone and to release the switch when he did.

The clinician has a choice of three sets of instructions to introduce the subject to his task. (The third set is actually a subset of either one of the first two). The first, introduced by Corso (1955), instructs the subject to press and release the switch so that the tone is always just barely audible. A second, and probably the most widely used (Grason-Stadler, 1963b; Jerger, 1960), instructs the subject to press the switch when the tone is just heard and release it when it is just not heard. Harbert and Young (1964) and others (Pestalozza & Cioce, 1962; Sorensen, 1962), have suggested a third set, instructing the subject to respond to the test frequency only so long as it is subjectively tonal in quality.

Reger pointed out, "The testing skill of the examiner [during Bekesy audiometry] is limited to instructing the patient how to take the test and to adjust the instruments controls (1952, p. 1334)."

Palva stated, "If the subject does not fully understand his share of the test, there is little hope for accuracy in the results (1956b, p. 1525)."

Subjects in numerous studies apparently did not understand their share of the task as published results show trace widths varying anywhere from 1.5 to 30 decibels wide. (See Table I). According to Epstein (1960) there definitely seems to be "wide swingers" and "narrow swingers" within the normal hearing population.

It is obvious that critical criterial measures by any method of interpretation are obliterated when trace widths extend to 30 decibels wide. Jerger (1960) had sixteen subjects that could not be classified into one of his four types because, "in some of these, excessive tracing width (30 to 40 decibels) obscures the relationship between C [continuous] and I [interrupted] (pp. 281-282)."

Before any investigation of the utility and possible refinement of Békésy typings for auditory pathologies could be investigated, a preliminary study was necessary to determine whether or not clinical subjects could meet standard criterial measures. Normal swingwidth has been reported to be 7-10 decibels (Hirsh, 1962; Lundborg, 1952).

The major advantage to be gained from training subjects to a criterion would be the establishment of a realistic baseline from which other variables and results could be compared. If a subject could meet this swingwidth prior to the recording of threshold, then a realistic baseline would serve to strengthen, modify or improve classification of Békésy tracings for diagnosing auditory pathologies.

B. Statement of the Problem.

Can a clinical population meet and maintain a reliable Békésy swingwidth which will reflect the accepted limits for normal variation around threshold?

Hypothesis: A clinic population can meet and maintain a ±5 decibel variability around threshold on Békésy audiometry.

C. Procedure and Design.

Of the first 50 subjects, 25 received standard instructions first, and 25 received modified instructions first. One subject required pantomime instructions while another found the task impossible due to a motor problem. In all cases, the subjects were experiencing their first introduction to Békésy audiometry. Age range of the subjects was 10 to 73.

D. Instructions. (Numbers 1 and 2 to be counter balanced).

1. Read standard instructions (See Appendix B).

or

2. Read modified instructions (See Appendix C).
3. Give practice session beginning at 500 Hz down to 200 Hz. Reverse chart and observe swingwidth

(envelope of pen movement) as frequency moves from low to high.

4. If envelope is equal to or less than 10 decibels, begin recording.
5. If envelope is greater than 10 decibels, stop.
6. If standard instructions (#1) were used first, go back in with patient and read modified instructions. If modified instructions (#2) were used first, then proceed to #7.
7. Give second practice session from 500 Hz down to 200 Hz. Reverse chart and observe envelope. If less than or equal to 10 decibels, begin recording.
8. If swing is still greater than 10 decibels, stop.
9. Show the patient a sample audiogram with a threshold tracing on it that is less than 10 decibels wide. Explain what the lines signify and show what its limits are to be (10 decibels). Remind them of the white line concept.
10. Give third practice session from 500 Hz down to 200 Hz or hold frequency at 200 Hz until they get accustomed to listening to the low tone.
11. If 10 decibel envelope is still not achieved, take patient to the equipment and show it in operation (Have pen writing - an old audiogram can be used numerous times for this). The analogy of the white line to threshold can be used while showing and

explaining what happens when the switch is pushed or released. Show, by tracing, what the maximum swingwidth can be (10 decibels).

12. Return patient to room and begin again from 500 Hz down to 200 Hz, or hold chart at 200 Hz, if envelope is 10 decibels drop pen and begin recording. If the envelope becomes larger than 10 decibels later in the sweep, stop chart and raise pen. (Do not move the pen or the chart). Go back in room and tell patient he is still waiting too long to work the switch. "You must pay close attention and listen for the tone coming and going, and press the switch the instant you hear the tone, and release it the instant it's gone. You can't let your attention wander. If you get confused, take your finger off the switch, and the tone will get louder. What do you do the instant you hear the tone?" They should say "push it." "And what do you do the instant you don't hear the tone?" They should say, "release it" or "let go."

13. After the tracing is obtained for the interrupted tone, return to the subject's room and read directions for continuous tone. These are found in Appendix C.

14. After the sweep tracings are completed, run fixed frequency tracings, always at least at 500 Hz,

2000 Hz and 4000 Hz. Do interrupted first, then continuous at each frequency. These tracings, like the sweep tracings, must be 10 decibels wide or less. See Appendix C.

15. Allow a 5-10 minute rest period.
16. Begin test sequence in opposite ear, if it is to be tested.

E. Results.

Of those 25 subjects receiving the standard instructions first, only 5 were able to meet the ±5 decibels swingwidth criterion initially. Modified instructions were then given. Of those subjects receiving the modified instructions first, only one could not meet the criterion. Upon questioning it was learned that an arthritic problem prevented it. All but this one subject met the ±5 decibels swingwidth criterion and all but five were able to maintain it throughout the test session. In view of the above results, the next 73 subjects received only the modified instructions.

F. Discussion.

The modified instructions were superior to the standard instructions when introducing a subject to Békésy audiometry. They were superior in that they enabled the subject to better understand his task, and they provided motivation for attending to the task throughout the test session.

The key word in the modified instructions that seemed most helpful was "instant," i.e., "the instant you hear," or "the instant you don't hear." Also the analogy of referring to their threshold as a white line down the center of the highway helped the subject understand his share of the task.

Positive reinforcement in the form of praise was given when the examiner changed the headset and/or when further instructions were given for the fixed frequency tracings. Negative reinforcement was given throughout the test session as required. Such phrases as: "What are you doing?", "Wake up and pay attention, we're almost through," "You have to concentrate on this task," "If you don't understand this task, tell me and I'll explain it again," "You're failing the test - you're going too far away from the 'white line,'" "You can do better than that - it's not very difficult," were used and resulted in the subject making a greater effort to perform satisfactorily.

G. Conclusion.

The hypothesis that a typical clinic population can meet and maintain a ±5 decibel swingwidth criterion on Békésy audiometry is retained.

APPENDIX B

Standard Instructions for Békésy Audiometry

"When I put these earphones on, you are going to hear a beeping sound in your ear. As long as you don't do anything the sound will keep getting louder. But you can make it fade away by holding down this switch. When you let up on the switch the sound will get louder again. Now, here is what I want you to do. Listen very carefully, and, as soon as you hear the beeping sound, hold this switch down until you can't hear it anymore. As soon as the beeping sound is gone, let up on the switch until it comes back. Then, as soon as you hear it again, hold the switch down until it goes away again, and so forth. The idea is to keep going back and forth from where you can just hear the beeping sound to where you can just not hear it any more. Never let the sound get very loud and never let it stay away too long. Hold this switch down as soon as you hear the sound, then let it up as soon as the sound is gone."

Following these instructions a tracing was made with the periodically interrupted (I) test signal. At the termination of this tracing the subject was reinstructed as follows:

"Now we are going to do the same thing again, but this time the sound will be steady instead of beeping on and off. Your job is still the same. Hold the switch down as soon as you hear the steady sound, and let it up as soon as the steady sound goes away (Jerger, 1960, p. 277)."

APPENDIX C

Modified Instructions for Békésy Audiometry

During this test your task will be to listen for a tone going on and off. The <u>instant</u> you hear or think you hear a beeping tone, I want you to push down on this switch and keep it down. When the switch is pushed down, the tone will start to fade away. The <u>instant</u> you no longer hear the tone, let the switch up, and the tone will come back. The first tones you'll hear will be very low like the lowest pitch on a piano. And as you press and release the switch, the tone will become louder and softer and at the same time it will get higher and higher in pitch, as if it's moving up the piano keyboard.

It's very important that you press the switch and keep it down the <u>instant</u> you think you hear the tone and that you release the switch the <u>instant</u> it's gone. Don't wait to make sure you hear or don't hear it before working the switch.

In order to give you an idea of what your task is going to be, this comparison may make it clearer. Imagine your threshold is the white line down the middle of the highway. The white line is the point separating what you <u>can</u> hear from what you <u>cannot</u> hear. If you had to drive down that line, in order to pass a driver's test I would allow you to veer only so far to either side. If you went too far, you would fail. The same idea applies here. If you wait too long to push or release the switch, the tone will veer too much from your threshold and we'll have to start over.

Discuss masking - If you hear a "shishing" sound or something that sounds like wind and rain blowing, don't press the switch for that sound. Just press the switch when you hear a beeping tone.

Tell them which ear the tone will be in first. If used, tell them which ear will have the masking sound in it.

Ask if the task is understood.

Go back to number 3 in the test procedure.

Continuous Tone.

When the interrupted sweep is finished, go in and tell them, "Now we're going to do the same thing again, only this time the tone will be a steady tone and won't go on and off like the one you just heard. Work the switch the same way. The instant you hear the tone, press the switch down and keep it down until the tone is gone and the instant it's gone, release the switch. The tones will again start very low and go up to high just as they did before."

Ask if the task is understood.

Directions for Fixed Frequency Tracings.

Now you will hear a tone that does not get higher or lower in pitch, but will be the same tone going on and off for approximately 2 minutes. After the beeping tone has stopped, begin to listen for that same tone again, only this time it will be a continuous tone.

In other words, the first time you hear the tone, it will be going on and off. After a while it will stop completely and when it comes back on it will be a continuous or steady tone. You will work the switch the same as you've been doing. Press it the <u>instant</u> you hear the tone and release it the <u>instant</u> its gone.

We will do this same thing with 2 or 3 different tones. First you will hear the interrupted or beeping tone and then you will listen for that same tone as a steady tone.

Remember if you hear a [ʃ] sound in this ear (point to the ear where masking will be if used) don't push the switch for that sound. Just work the switch for the tone.

Do you understand?

APPENDIX D

GRANITZ' CRITERIA FOR CLASSIFICATION OF BÉKÉSY TYPES

Visual Description	Numerical Value of Separation			Qualifying Criterion
	500 Hz	2kHz	4kHz	
Type I C & I interweave	<7dB	<7dB	<7dB	
Type II C & I interweave in low frequencies, drop 10-15dB in higher frequencies	<7dB	>10<20dB ±3dB	>10<20dB ±3dB	1. C may narrow in higher frequencies. 2. If 4k has greater separation than 2k and separation at 2k is > 4.5dB.
Type III C drops precipitously 40-50dB	Sharp dropout	Sharp dropout	Sharp dropout	
Type IV C separates from I in low frequencies, D II 20dB	>10dB ±3dB	>20dB	>20dB	C & I may overlap in mid-frequencies

Explanation of Classification of Békésy Types

The visual description in the table corresponds to the visual examples given by Jerger (1960). (See Figure 1 page 22 of this text).

The numerical quantification was derived primarily from Jerger's written description of the types in the original article.

The classification system is applied in the following manner. A midline is drawn through the swingwidth for both the continuous and interrupted tracings at 500, 2000 and 4000 Hz.

To be classified Type I, there has to be less than 7 dB separation between the interpolated midpoints at 500, 2000 and 4000 Hz.

To be classified Type II, the separation at 500 Hz must be less than 7 dB. The separation at 2000 and 4000 Hz has to be greater than 10 dB and less than 20 dB. There are two qualifying criterion for Type II if the Bekesy tracing does not meet the above criterion. If 2000 and 4000 Hz only show a separation of 7 dB, but the swingwidth of the continuous tone is decidedly narrower in the higher frequencies it will be classified as Type II. If 4000 Hz has greater separation than 2000 Hz and the separation at 2000 Hz is greater than 4.5 dB, it is classified as Type II

To be classified Type III, the continuous tone will show a progressive decrease until it reaches the limits of the audiometer.

To be classified Type IV, the continuous tone shows separation from the interrupted greater than 10 dB at 500 Hz and greater than 20 dB at 2000 and 4000 Hz. It is differentiated from Type III in that the continuous tone will achieve a stable tracking level.

APPENDIX E

TABLE OF DATA ACCUMULATED ON ALL SUBJECTS

Key to Appendix E

N	Normal
Ab	Abnormal
*	Not done
NA	Not available
AT	Acoustic tumor
LCP	Left canal paresis
RCP	Right canal paresis
LDP	Left directional preponderance
RDP	Right directional preponderance
LSN	Left spontaneous nystagmus
RSN	Right spontaneous nystagmus
CVD	Central vestibular disorder

TABLE XVI

DATA ACCUMULATED ON NORMAL GROUP

#	Age	Sex	Disc. 40dB SL	- =neg.recru. + =pos.recru.	ABLB	AMLB	SISI		Owens TDT		Xray	Neuro-logical	ENG
1	41	F	Q 96%	500	*	*	500	*	500	I	N	N	*
			N 84%	2k	*		2k	0%	2k	I			
				4k	*		4k	*	4k	I			
2	41	F	Q 100%	500	*	*	500	*	500	I	N	N	*
			N 76%	2k	*		2k	0%	2k	I			
				4k	*		4k	*	4k	I			
3	47	F	Q 100%	500	*	*	500	0%	500	I	*	*	N
			N 92%	2k	*		2k	0%	2k	I			
				4k	*		4k	0%	4k	I			
4	38	F	Q 100%	500	*	*	500	*	500	I	N	*	N
			N 92%	2k	*		2k	*	2k	I			
				4k	*		4k	*	4k	I			
5	38	F	Q 100%	500	*	*	500	*	500	I	N	*	N
			N 100%	2k	*		2k	*	2k	I			
				4k	*		4k	*	4k	I			
6	30	M	Q 96%	500	*	*	500	0%	500	I	*	*	*
			N 88%	2k	*		2k	0%	2k	I			
				4k	*		4k	0%	4k	I			
7	58	F	Q 100%	500	*	*	500	*	500	I	N	*	*
			N 92%	2k	*		2k	*	2k	I			
				4k	*		4k	*	4k	I			
8	58	F	Q 100%	500	*	*	500	0%	500	I	N	*	*
			N 100%	2k	*		2k	0%	2k	I			
				4k	*		4k	100%	4k	I			
9	64	F	Q 100%	500	*	*	500	*	500	*	*	*	*
			N 96%	2k	*		2k	*	2k	*			
				4k	*		4k	*	4k	*			

TABLE XVI (supplement, subjects 1-9)

#	Sweep Tracing Pulsed/cont. dB difference				Fixed Tracing Pulsed/cont. dB difference				Swing Width Pulsed			Swing Width Continuous			ENT Findings
	Type	500	2k	4k	Type	500	2k	4k	500	2k	4k	500	2k	4k	
1	I	0	2	4	I	0	0	6	9.5	9.0	8.5	9.5	9.0	8.0	Normal
2	I	0	0	0	I	0	2	0	10.0	9.5	9.5	9.5	8.5	8.0	Normal
3	I	0	0	0	I	0	3	3	9.0	9.0	8.5	9.0	9.5	9.0	Normal
4	I	0	0	0	I	2	5	2	7.0	6.0	8.5	6.0	5.5	6.0	Normal
5	I	0	0	0	I	5	6	0	9.5	7.5	7.0	6.5	5.0	6.5	Normal
6	I	0	0	0	I	0	10	0	10.0	12.5	9.0	12.5	10.5	10.0	Normal
7	I	0	0	0	I	0	0	0	9.5	10.0	9.0	7.5	9.0	7.5	Normal
8	I	0	0	0	I	0	0	7	8.0	8.5	7.5	10.5	7.5	7.5	Normal
9	I	0	0	0	I	0	0	0	8.0	10.5	10.5	8.0	8.5	10.5	Normal

TABLE XVI

DATA ACCUMULATED ON NORMAL GROUP, contd.

#	Age	Sex	Disc. 40dB SL		- =neg.recru. + =pos.recru. ABLB		AMLB	SISI		Owens TDT		Xray	Neuro-logical	ENG
10	32	F	Q	*	500	*	*	500	*	500	*	*	*	*
			N	*	2k	*		2k	*	2k	*			
					4k	*		4k	*	4k	*			
11	24	F	Q	*	500	*	*	500	*	500	*	*	*	*
			N	*	2k	*		2k	*	2k	*			
					4k	*		4k	*	4k	*			
12	26	M	Q	*	500	*	*	500	*	500	*	*	*	*
			N	*	2k	*		2k	*	2k	*			
					4k	*		4k	*	4k	*			
13	31	F	Q	*	500	*	*	500	*	500	*	*	*	*
			N	*	2k	*		2k	*	2k	*			
					4k	*		4k	*	4k	*			
14	26	M	Q	*	500	*	*	500	*	500	*	*	*	*
			N	*	2k	*		2k	*	2k	*			
					4k	*		4k	*	4k	*			
15	24	F	Q	*	500	*	*	500	*	500	*	*	*	*
			N	*	2k	*		2k	*	2k	*			
					4k	*		4k	*	4k	*			
16	29	M	Q	*	500	*	*	500	*	500	*	*	*	*
			N	*	2k	*		2k	*	2k	*			
					4k	*		4k	*	4k	*			

TABLE XVII (supplement, subjects 10-16)

#	Sweep Tracing Pulsed/cont. dB difference				Fixed Tracing Pulsed/cont. dB difference				Swing Width						ENT Findings
									Pulsed			Continuous			
	Type	500	2k	4k	Type	500	2k	4k	500	2k	4k	500	2k	4k	
10	I	0	3	2	I	0	0	0	9.5	10.0	10.0	9.5	9.0	9.5	Normal
11	I	0	0	0	I	0	0	0	6.0	4.5	5.0	6.0	5.5	5.5	Normal
12	I	0	0	0	I	0	0	0	6.0	6.0	6.0	6.5	5.5	6.0	Normal
13	I	0	0	0	I	0	0	0	5.5	5.0	7.0	5.5	5.5	6.5	Normal
14	I	0	0	0	I	0	0	0	10.0	8.5	6.5	9.5	8.0	7.5	Normal
15	I	0	0	0	I	0	0	0	9.5	9.5	8.0	8.5	8.0	7.5	Normal
16	I	0	0	0	I	0	0	0	6.5	8.5	7.0	6.5	6.0	6.0	Normal

TABLE XVIII

DATA ACCUMULATED ON CONDUCTIVE GROUP

#	Age	Sex	Disc. 40dB sl		- =neg.recru. + =pos.recru.	ABLB	AMLB	SISI		Owens TDT		Xray	Neuro-logical	ENG
17	28	F	Q	100%	500	*	*	500	*	500	*	*	*	*
			N	100	2k	*	*	2k	*	2k	*			
					4k	*		4k	*	4k	*			
18	30	F	Q	96%	500	*	*	500	*	500	I	N	*	*
			N	84	2k	*		2k	*	2k	II			
					4k	*		4k	*	4k	III			
19	27	F	Q	100%	500	*	*	500	*	500	I	N	*	RCP
			N	96	2k	*		2k	*	2k	I[illegible]			
					4k	*		4k	*	4k	I			
20	14	F	Q	100%	500	*	*	500	*	500	*	*	*	*
			N	100	2k	*		2k	*	2k	*			
					4k	*		4k	*	4k	*			
21	14	M	Q	100%	500	*	*	500	*	500	*	*	*	*
			N	*	2k	*		2k	*	2k	*			
					4k	*		4k	*	4k	*			
22	17	F	Q	100%	500	*	*	500	*	500	*	*	*	*
			N	100	2k	*		2k	*	2k	*			
					4k	*		4k	*	4k	*			
23	18	F	Q	100%	500	*	*	500	*	500	*	*	*	*
			N	100	2k	*		2k	*	2k	*			
					4k	*		4k	*	4k	*			
24	12	M	Q	100%	500	*	*	500	*	500	*	*	*	*
			N	*	2k	*		2k	*	2k	*			
					4k	*		4k	*	4k	*			
25	18	F	Q	100%	500	*	*	500	*	500	*	*	*	*
			N	96	2k	-		2k	*	2k	*			
					4k	*		4k	*	4k	*			
26	18	F	Q	100%	500	*	*	500	*	500	*	*	*	*
			N	100	2k	*		2k	*	2k	*			
					4k	*		4k	*	4k	*			

TABLE XVIII (supplement, subjects 17-26)

#	Sweep Tracing Pulsed/cont. dB difference				Fixed Tracing Pulsed/cont. dB difference				Swing Width Pulsed			Swing Width Continuous			ENT Findings
	Type	500	2k	4k	Type	500	2k	4k	500	2k	4k	500	2k	4k	
17	I	0	0	0	I	0	0	0	8.0	8.5	6.5	6.5	6.5	6.5	Eustachian tube malfunction.
18	I	0	0	0	I	0	0	5	8.5	10.0	9.5	8.5	7.5	6.0	Conductive
19	I	0	0	0	I	0	0	0	9.0	7.5	8.5	9.5	8.0	7.5	Conductive
20	I	0	0	0	I	0	0	0	8.5	9.0	7.5	8.0	7.5	7.5	Otitis media
21	I	0	0	0	I	0	0	0	8.5	9.0	9.0	9.0	8.0	8.0	Otitis media
22	I	0	0	0	I	0	0	0	8.0	8.5	7.0	9.0	9.0	9.0	Otitis media
23	I	0	0	0	I	0	0	0	8.5	8.5	8.5	8.5	8.5	8.0	Perforated tympanic membrane
24	I	0	0	0	I	0	0	0	9.0	8.5	8.5	10.0	8.5	8.5	Otitis media
25	I	0	0	0	I	0	0	0	7.5	9.0	9.5	8.5	7.5	6.5	Perforated tympanic membrane
26	I	0	0	0	I	0	3	8	6.5	7.0	6.0	7.5	7.0	6.0	Otitis media

TABLE XVIII

DATA ACCUMULATED ON MIXED GROUP

#	Age	Sex	Disc. 40dB SL	- =neg.recru. + =pos.recru. ABLB		AMLB	SISI		Owens TDT		Xray	Neuro-logical	ENG
27	64	F	Q 68%	500	*	*	500	*	500	I	N	N	N
			N 48%	2k	*		2k	*	2k	III			
				4k	*		4k	*	4k	III			
28	64	F	Q 100%	500	*	*	500	*	500	I	N	N	N
			N 88%	2k	*		2k	*	2k	II			
				4k	*		4k	*	4k	III			
29	59	M	Q 100%	500	*	*	500	0%	500	I	N	*	N
			N 96%	2k	*		2k	0%	2k	I			
				4k	*		4k	0%	4k	I			
30	51	F	Q 100%	500	*	*	500	*	500	*	*	*	*
			N 96%	2k	*		2k	*	2k	*			
				4k	-		4k	*	4k	*			
31	61	F	Q 100%	500	*	*	500	*	500	*	*	*	*
			N 92%	2k	*		2k	*	2k	*			
				4k	*		4k	*	4k	*			
32	57	F	Q 88%	500	*	*	500	*	500	*	*	*	*
			N 80%	2k	*		2k	*	2k	*			
				4k	*		4k	*	4k	*			

TABLE XVIII(supplement, subjects 27-32)

#	Sweep Tracing Pulsed/cont. dB difference Type	500	2k	4k	Fixed Tracing Pulsed/cont. dB difference Type	500	2k	4k	Swing Width Pulsed 500	2k	4k	Continuous 500	2k	4k	ENT Findings
27	I	0	0	3	I	2	2	8	8.5	7.5	6.0	8.5	5.5	4.5	Mixed loss
28	I	0	0	0	II	0	10	15	10.0	8.5	7.5	10.0	8.0	8.5	Mixed loss
29	I	0	0	0	I	0	0	4	10.0	9.5	10.0	9.0	9.0	7.5	Mixed loss
30	I	4	6	5	I	0	6	5	9.5	9.5	9.5	9.5	6.0	6.5	Mixed loss
31	I	0	3	5	I	0	6	7	10.0	9.0	8.0	9.5	7.0	6.0	Mixed loss
32	I	2	0	2	I	0	7	5	7.0	6.5	6.0	6.5	4.5	4.5	Mixed loss

TABLE XIX

DATA ACCUMULATED ON COCHLEAR GROUP

#	Age	Sex	Disc. 40dB SL		- =neg.recru. + =pos.recru.	ABLB	AMLB	SISI		Owens TDT		Xray	Neuro-logical	ENG
33	49	M	Q	88%	500	*	-	500	*	500	I	N	N	*
			N	84%	2k	*		2k	0%	2k	I			
					4k	*		4k	90%	4k	II			
34	49	M	Q	88%	500	*	-	500	*	500	I	N	N	*
			N	84%	2k	*		2k	0%	2k	I			
					4k	*		4k	90%	4k	II			
35	73	F	Q	92%	500	*	*	500	0%	500	*	*	*	*
			N	40%	2k	*		2k	100%	2k	II			
					4k	*		4k	100%	4k	II			
36	55	M	Q	68%	500	+	*	500	0%	500	I	N	N	*
			N	56%	2k	*		2k	0%	2k	I			
					4k	*		4k	0%	4k	I			
37	59	F	Q	32%	500	*	*	500	0%	500	II	*	*	*
			N	12%	2k	*		2k	100%	2k	III			
					4k	*		4k	100%	4k	III			
38	47	F	Q	100%	500	+	*	500	0%	500	I	*	*	N
			N	100%	2k	*		2k	0%	2k	I			
					4k	*		4k	0%	4k	I			
39	69	M	Q	4%	500	-	*	500	0%	500	I	N	N	*
			N	0%	2k	*		2k	100%	2k	II			
					4k	*		4k	100%	4k	II			
40	69	M	Q	72%	500	*	*	500	0%	500	I	N	N	*
			N	48%	2k	*		2k	100%	500	II			
					4k	*		4k	100%	4k	II			
41	66	M	Q	0%	500	*	*	500	100%	500	II	N	*	LCP
			N	0%	2k	*		2k	100%	2k	II			
					4k	*		4k	100%	4k	II			

TABLE XIX (supplement, subjects 33-41)

#	Sweep Tracing Pulsed/cont. dB difference Type	500	2k	4k	Fixed Tracing Pulsed/cont. dB difference Type	500	2k	4k	Swing Width Pulsed 500	2k	4k	Continuous 500	2k	4k	ENT Findings
33	I	0	0	8	IV	10	30	7	9.5	10.5	9.0	10.0	8.5	5.5	Acoustic trauma
34	I	6	4	0	IV	12	20	15	10.0	9.5	8.5	8.5	8.0	5.0	Acoustic trauma
35	I	0	0	3	II	3	14	13	5.5	9.5	6.0	6.5	6.0	3.0	Vascular
36	IV	13	7	6	II	6	7	15	7.5	7.5	6.5	8.0	5.0	4.0	Meniere's
37	I	3	5	6	I	0	4	5	8.5	5.5	6.0	7.5	6.0	5.5	Meniere's
38	I	0	0	0	I	0	0	0	11.5	11.5	11.5	11.5	11.5	11.5	Meniere's
39	I	0	0	0	II	0	2	9	10.0	9.5	7.0	4.5	5.5	3.5	Meniere's
40	I	0	0	2	I	0	4	3	9.0	8.0	7.0	8.5	7.0	4.5	Acoustic trauma
41	I	0	2	0	I	7	7	5	7.5	6.0	6.0	5.5	4.5	7.0	Meniere's

TABLE XIX

DATA ACCUMULATED ON COCHLEAR GROUP, contd.

#	Age	Sex	Disc. 40dB SL	- =neg.recru. + =pos.recru.	ABLB	AMLB	SISI		Owens TDT		Xray	Neuro-logical	ENG
42	63	M	Q 36%	500	*	*	500	10%	500	I	N	N	N
			N 8%	2k	*		2k	100%	2k	I			
				4k	*		4k	100%	4k	II			
43	25	F	Q 92%	500	*	*	500	0%	500	*	*	*	*
			N 80%	2k	*		2k	0%	2k	I			
				4k	*		4k	100%	4k	II			
44	58	F	Q 56%	500	+	*	500	0%	500	I	N	*	*
			N 28%	2k	+		2k	100%	2k	I			
				4k	+		4k	100%	4k	II			
45	54	M	Q 100%	500	*	+	500	0%	500	I	N	N	N
			N 92%	2k	*		2k	0%	2k	I			
				4k	*		4k	0%	4k	II			
46	54	M	Q 100%	500	*	+	500	0%	500	I	N	N	N
			N 92%	2k	*		2k	0%	2k	II			
				4k	*		4k	0%	4k	III			
47	32	M	Q 96%	500	*	*	500	0%	500	I	N	N	N
			N 64%	2k	*		2k	0%	2k	I			
				4k	+		4k	100%	4k	II			
48	38	M	Q 96%	500	*	*	500	0%	500	*	N	N	LCP
			N 84%	2k	+		2k	100%	2k	*			
				4k	+		4k	100%	4k	*			
49	45	M	Q 80%	500	*	*	500	0%	500	*	Ab	NA	N
			N 40%	2k	+		2k	15%	2k	II			
				4k	*		4k	100%	4k	II			
50	79	M	Q 84%	500	*	*	500	0%	500	*	N	*	*
			N 64%	2k	*		2k	0%	2k	II			
				4k	*		4k	100%	4k	II			
51	51	F	Q 80%	500	+	*	500	100%	500	I	N	*	*
			N 88%	2k	*		2k	100%	2k	I			
				4k	+		4k	100%	4k	I			

TABLE XIX (supplement, subjects 42-51)

#	Sweep Tracing Pulsed/cont. dB difference Type	500	2k	4k	Fixed Tracing Pulsed/cont. dB difference Type	500	2k	4k	Swing Width Pulsed 500	2k	4k	Continuous 500	2k	4k	ENT Findings
42	I	3	0	2	II	7	8	15	5.0	6.0	5.0	7.0	5.5	4.5	Meniere's
43	I	0	4	0	II	0	7	8	6.0	5.5	7.0	5.0	4.5	4.0	Vascular
44	I	0	5	3	I	0	7	5	9.5	8.0	8.0	9.5	9.0	10.0	Acoustic trauma
45	I	0	0	0	I	0	2	7	8.5	7.5	7.0	7.5	6.5	8.0	Head trauma
46	I	0	0	0	II	0	0	8	7.5	6.0	7.0	7.5	9.0	6.0	Head trauma
47	I	0	0	0	I	0	0	3	8.5	9.0	6.5	9.5	5.5	6.0	Acoustic trauma
48	I	0	7	2	I	0	5	5	10.0	9.5	10.0	9.0	9.0	6.0	Meniere's
49	I	5	0	0	II	0	5	10	9.5	9.5	9.0	9.5	9.0	10.0	Meniere's
50	II	0	9	10	II	0	18	18	7.0	6.5	6.5	5.5	2.3	2.3	Acoustic trauma
51	IV	18	10	5	IV	18	15	10	9.0	11.5	9.0	9.0	9.0	8.0	Viral

TABLE XIX

DATA ACCUMULATED ON COCHLEAR GROUP, contd.

#	Age	Sex	Disc. 40dB SL		- =neg.recru. + =pos.recru.	ABLB	AMLB	SISI		Owens TDT		Xray	Neuro-logical	ENG
52	73	F	Q	96%	500	*	+	500	0%	500	*	N	*	RCP
			N	76%	2k	*		2k	0%	2k	II			
					4k	*		4k	0%	4k	III			
53	59	F	Q	50%	500	*	*	500	100%	500	III	N	N	*
			N	0%	2k	+		2k	100%	2k	III			
					4k	+		4k	100%	4k	III			
54	64	M	Q	96%	500	*	*	500	0%	500	I	N	N	*
			N	88%	2k	*		2k	0%	2k	I			
					4k	*		4k	100%	4k	I			
55	64	M	Q	80%	500	+	*	500	0%	500	I	N	N	*
			N	72%	2k	*		2k	100%	2k	II			
					4k	*		4k	100%	4k	II			
56	66	F	Q	68%	500	*	*	500	0%	500	I	N	N	N
			N	64%	2k	*		2k	100%	2k	II			
					4k	*		4k	100%	4k	II			
57	66	F	Q	92%	500	*	*	500	0%	500	I	N	N	N
			N	88%	2k	*		2k	0%	2k	II			
					4k	*		4k	100%	4k	II			
58	10	M	Q	72%	500	+	*	500	0%	500	*	N	*	*
			N	*	2k	+		2k	100%	2k	*			
					4k	+		4k	100%	4k	*			
59	48	M	Q	80%	500	*	*	500	*	500	I	*	*	*
			N	48%	2k	*		2k	*	2k	II			
					4k	*		4k	*	4k	II			
60	62	F	Q	52%	500	*	*	500	0%	500	I	*	*	*
			N	60%	2k	*		2k	100%	2k	II			
					4k	*		4k	100%	4k	III			
61	45	M	Q	44%	500	*	*	500	0%	500	*	*	*	*
			N	*	2k	*		2k	0%	2k	*			
					4k	*		4k	0%	4k	*			

TABLE XIX (supplement, subjects 52-61)

#	Sweep Tracing Pulsed/cont. dB difference Type	500	2k	4k	Fixed Tracing Pulsed/cont. dB difference Type	500	2k	4k	Swing Width Pulsed 500	2k	4k	Continuous 500	2k	4k	ENT Findings
52	I	0	3	12	II	0	8	23	8.5	8.5	9.0	9.0	9.0	9.5	Vascular
53	IV	20	25	23	IV	29	18	15	6.0	6.0	6.0	5.0	4.0	3.0	Meniere's
54	I	0	6	5	II	4	10	10	5.0	5.5	6.0	5.5	2.5	2.5	Arterio-sclerosis
55	II	3	15	10	IV	8	12	12	4.5	4.0	4.5	4.5	2.0	1.5	Arterio-sclerosis
56	I	0	0	5	I	0	8	3	10.0	10.0	9.0	9.0	7.5	6.0	Vascular
57	I	0	5	7	II	0	12	10	9.0	9.0	9.5	7.0	7.0	6.3	Vascular
58	I	0	3	15	I	0	0	0	11.5	11.0	10.0	11.5	10.0	10.0	Viral
59	I	0	9	0	II	0	7	7	8.0	10.0	10.0	9.0	10.0	10.0	Acoustic trauma
60	II	0	20	12	II	4	7	10	8.5	7.5	7.0	7.5	6.0	4.5	Arterio-sclerosis
61	II	0	2	out	II	0	8	9	8.5	6.5	7.5	7.0	5.0	6.0	Acoustic trauma

TABLE XIX

DATA ACCUMULATED ON COCHLEAR GROUP, CONTD.

#	Age	Sex	Disc. 40dB SL	- =neg.recru. + =pos.recru.	ABLB	AMLB	SISI		Owens TDT		Xray	Neuro-logical	ENG
62	47	M	Q 92%	500	*	*	500	0%	500	I	N	*	N
			N 92%	2k	*		2k	0%	2k	I			
				4k	*		4k	100%	4k	I			
63	47	M	Q 96%	500	*	*	500	0%	500	I	N	*	N
			N 96%	2k	*		2k	0%	2k	I			
				4k	*		4k	0%	4k	II			
64	26	F	Q 96%	500	*	*	500	*	500	I	N	N	*
			N 80%	2k	*		2k	*	2k	I			
				4k	*		4k	*	4k	II			
65	19	F	Q 100%	500	*	*	500	0%	500	I	*	*	*
			N 80%	2k	+		2k	0%	2k	I			
				4k	+		4k	100%	4k	II			
66	28	F	Q 16%	500	+	*	500	0%	500	I	*	*	N
			N 4%	2k	*		2k	100%	2k	II			
				4k	+		4k	100%	4k	II			
67	28	M	Q 56%	500	*	*	500	*	500	*	*	*	*
			N 56%	2k	+		2k	100%	2k	*			
				4k	*		4k	0%	4k	*			
68	32	F	Q 100%	500	*	*	500	*	500	*	*	*	RCP
			N 86%	2k	*		2k	0%	2k	I			
				4k	*		4k	0%	4k	I			
69	61	F	Q 72%	500	+	*	500	90%	500	I	*	*	N
			N 60%	2k	*		2k	100%	2k	II			
				4k	+		4k	100%	4k	II			
70	46	M	Q 90%	500	*	*	500	0%	500	I	*	*	*
			N 64%	2k	*		2k	25%	2k	I			
				4k	*		4k	85%	4k	*			
71	60	F	Q 52%	500	*	*	500	100%	500	I	*	*	RCP
			N 28%	2k	*		2k	100%	2k	I			
				4k	*		4k	100%	4k	II			

TABLE XIX (supplement, subjects 62-71)

#	Sweep Tracing Pulsed/cont. dB difference Type	500	2k	4k	Fixed Tracing Pulsed/cont. dB difference Type	500	2k	4k	Swing Width Pulsed 500	2k	4k	Continuous 500	2k	4k	ENT Findings
62	I	0	0	5	II	0	4	11	10.0	8.5	9.5	9.0	7.0	8.0	Acoustic trauma
63	I	0	0	5	II	0	5	8	9.0	7.0	10.0	8.0	7.0	9.0	Acoustic trauma
64	I	0	0	0	II	0	0	12	8.0	7.0	9.5	7.5	7.0	4.5	Vascular
65	I	0	0	0	II	0	6	15	5.5	4.5	4.0	4.0	3.0	3.0	Viral
66	II	7	5	10	II	0	10	10	5.5	4.0	4.0	7.5	2.0	2.0	Meniere's
67	I	0	2	8	I	0	10	3	8.0	8.5	7.0	9.5	4.5	9.0	Acoustic trauma
68	I	0	0	4	II	0	5	6	11.0	10.0	13.5	11.0	9.0	10.0	Meniere's
69	II	2	7	13	II	3	8	14	10.5	8.5	9.0	8.5	7.0	3.0	Meniere's
70	I	10	0	4	II	2	6	8	11.5	10.5	10.5	10.5	9.0	7.5	Meniere's
71	I	0	5	6	II	10	10	13	6.0	7.0	9.0	5.5	4.0	3.0	Meniere's

TABLE XIX

DATA ACCUMULATED ON COCHLEAR GROUP, contd.

#	Age	Sex	Disc. 40dB SL	- =neg.recru. + =pos.recru.	ABLB	AMLB	SISI		Owens TDT		Xray	Neuro-logical	ENG
72	63	M	Q 84%	500	*	*	500	0%	500	I	*	*	LCP
			N 80%	2k	*		2k	95%	2k	I			
				4k	*		4k	100%	4k	I			
73	48	M	Q 72%	500	*	*	500	0%	500	I	*	*	LCP
			N 46%	2k	+		2k	100%	2k	I			
				4k	+		4k	100%	4k	I			
74	28	F	Q 96%	500	*	*	500	0%	500	I	*	*	*
			N 78%	2k	*		2k	0%	2k	I			
				4k	*		4k	0%	4k	I			
75	58	M	Q 40%	500	*	*	500	0%	500	I	*	*	RCP
			N 28%	2k	*		2k	90%	2k	I			
				4k	*		4k	100%	4k	I			
76	49	F	Q 100%	500	*	*	500	*	500	I	*	*	LCP
			N 100%	2k	*		2k	*	2k	I			
				4k	*		4k	*	4k	I			

TABLE XIX. (supplement, subjects 72-76)

#	Sweep Tracing Pulsed/cont. dB difference Type	500	2k	4k	Fixed Tracing Pulsed/cont. dB difference Type	500	2k	4k	Swing Width Pulsed 500	2k	4k	Continuous 500	2k	4k	ENT Findings
72	II	0	8	8	II	0	8	15	6.0	6.0	6.0	5.5	3.0	3.0	Meniere's
73	I	10	0	8	I	0	0	8	6.0	5.0	6.0	5.0	5.0	3.5	Meniere's
74	I	0	0	0	I	0	0	5	9.5	10.5	8.0	9.0	10.0	6.0	Meniere's
75	I	10	4	6	II	0	4	12	10.0	9.5	9.5	10.0	9.5	8.5	Meniere's
76	I	0	0	0	II	0	4	9	7.5	8.0	8.0	7.0	7.5	3.5	Acoustic trauma

TABLE XX

DATA ACCUMULATED ON RETROCOCHLEAR GROUP

#	Age	Sex	Disc. 40dB SL		- =neg.recru. + =pos.recru.	ABLB	AMLB	SISI		Owens TDT		Xray	Neuro-logical	ENG
77	22	F	Q	96%	500	*	*	500	0%	500	III	*	*	*
			N	48%	2k	-		2k	0%	2k	III			
					4k	*		4k	0%	4k	III			
78	60	F	Q	*	500	*	*	500	0%	500	III	RAT	RAT	*
			N	*	2k	*		2k	100%	2k	III			
					4k	*		4k	0%	4k	III			
79	52	F	Q	28%	500	*	*	500	*	500	*	LAT	LAT	*
			N	*	2k	-		2k	80%	2k	*			
					4k			4k	70%	4k	*			
80	58	F	Q	*	500	+	*	500	*	500	*	RAT	RAT	*
			N	*	2k	+		2k	*	2k	*			
					4k	+		4k	*	4k	*			
81	33	M	Q	28%	500	*	*	500	0%	500	III	*	*	RCP
			N	8%	2k	*		2k	0%	2k	III			
					4k	*		4k	0%	4k	III			
82	49	F	Q	52%	500	*	*	500	*	500	III	*	RAT	*
			N	*	2k	*		2k	*	2k	III			
					4k	*		4k	*	4k	III			

TABLE XX (supplement, subjects 77-82)

#	Sweep Tracing Pulsed/cont. dB difference Type	500	2k	4k	Fixed Tracing Pulsed/cont. dB difference Type	500	2k	4k	Swing Width Pulsed 500	2k	4k	Continuous 500	2k	4k	ENT Findings
77	III	0	(out)		III		(out)				Unmeasurable.				Acoustic tumor
78	III		(out)		III		(out)		6.0	5.5	5.0	Unmeasurable.			Acoustic tumor
79	III		(out)		III		(out)		5.0	4.5	4.5	Unmeasurable.			Acoustic tumor
80	III	32	(out)		III		(out)		5.0	4.5	4.5	Unmeasurable.			Acoustic tumor
81	III		(out)		III		(out)		7.0	6.5	8.0	Unmeasurable.			Cholesteatoma
82	III		(out)		III		(out)				Unmeasurable				Acoustic tumor

TABLE XXI

DATA ACCUMULATED ON UNKNOWN GROUP

#	Age	Sex	Disc. 40dB SL		- =neg.recru. + =pos.recru.	ABLB	AMLB	SISI		Owens TDT		Xray	Neuro-logical	ENG
83	49	F	Q	92%	500	*	*	500	*	500	*	*	*	*
			N	88%	2k	*		2k	*	2k	*			
					4k	*		4k	*	4k	*			
84	54	F	Q	88%	500	*	*	500	0%	500	*	*	*	*
			N	80%	2k	*		2k	100%	2k	*			
					4k	*		4k	*	4k	*			
85	54	F	Q	92%	500	*	*	500	0%	500	*	*	*	*
			N	84%	2k	*		2k	90%	2k	*			
					4k	*		4k	*	4k	*			
86	59	F	Q	84%	500	*	*	500	0%	500	I	*	*	*
			N	60%	2k	*		2k	90%	2k	I			
					4k	*		4k	100%	4k	III			
87	58	F	Q	100%	500	*	*	500	0%	500	III	N	*	*
			N	100%	2k	*		2k	0%	2k	III			
					4k	*		4k	0%	4k	III			
88	53	F	Q	96%	500	*	*	500	0%	500	I	*	*	CVD
			N	84%	2k	*		2k	0%	2k	II			
					4k	*		4k	20%	4k	II			
89	20	M	Q	88%	500	*	*	500	*	500	*	N	*	*
			N	*	2k	*		2k	*	2k	*			
					4k	*		4k	*	4k	*			
90	20	M	Q	88%	500	*	*	500	*	500	*	N	*	*
			N	*	2k	*		2k	*	2k	*			
					4k	*		4k	*	4k	*			
91	68	F	Q	96%	500	*	*	500	0%	500	I	*	*	*
			N	72%	2k	*		2k	70%	2k	III			
					4k	*		4k	0%	4k	III			
92	56	M	Q	100%	500	*	*	500	*	500	I	*	*	*
			N	84%	2k	*		2k	0%	2k	I			
					4k	*		4k	100%	4k	I			

TABLE XXI (supplement, subjects 83-92)

#	Sweep Tracing Pulsed/cont. dB difference				Fixed Tracing Pulsed/cont. dB difference				Swing Width Pulsed			Swing Width Continuous			ENT Findings
	Type	500	2k	4k	Type	500	2k	4k	500	2k	4k	500	2k	4k	
83	I	0	5	6	I	5	8	5	10.0	9.5	8.0	8.0	7.5	5.0	Unknown
84	II	5	8	8	II	0	12	25	7.0	5.0	5.0	4.5	2.0	2.0	Unknown
85	I	0	7	0	II	3	9	25	7.0	5.5	6.0	5.0	4.0	4.0	Unknown
86	I	0	3	5	II	0	10	11	9.0	7.0	7.0	8.0	5.0	4.5	Unknown
87	I	0	2	4	II	0	5	9	7.5	6.0	7.0	6.0	7.0	6.0	Unknown
88	I	0	0	0	II	0	6	12	4.5	6.0	4.0	5.0	5.0	2.5	Unknown
89	II	0	10	13	I	4	5	7	4.5	6.0	5.5	6.0	3.5	3.5	Unknown
90	II	4	11	6	II	0	8	9	7.0	6.0	7.5	7.0	4.0	4.0	Unknown
91	I	0	3	6	II	4	5	8	7.0	7.0	7.5	8.5	6.0	5.5	Unknown
92	I	0	0	9	II	0	5	10	7.0	9.0	6.0	9.5	9.5	4.0	Unknown

TABLE XXI

DATA ACCUMULATED ON UNKNOWN GROUP, contd.

#	Age	Sex	Disc. 40dB SL	- =neg.recru. + =pos.recru. ABLB	AMLB	SISI	Owens TDT	Xray	Neuro-logical	ENG
93	55	F	Q 84%	500 *	*	500 0%	500 II	*	*	*
			N 60%	2k *		2k 0%	2k II			
				4k *		4k 0%	4k II			
94	55	F	Q 80%	500 *	*	500 0%	500 I	*	*	*
			N 72%	2k *		2k 0%	2k II			
				4k *		4k 0%	4k II			
95	64	F	Q 100%	500 *	*	500 *	500 *	N	*	*
			N *	2k *		2k *	2k *			
				4k *		4k *	4k *			
96	48	M	Q 76%	500 partial	*	500 100%	500 II	N	N	*
			N 76%	2k partial		2k 100%	2k III			
				4k *		4k 90%	4k II			
97	10	M	Q 60%	500 *	*	500 0%	500 *	N	*	*
			N *	2k *		2k 80%	2k *			
				4k *		4k 100%	4k *			
98	64	F	Q 100%	500 *	*	500 0%	500 I	N	N	N
			N 88%	2k *		2k 0%	2k I			
				4k *		4k 0%	4k I			
99	37	F	Q 84%	500 *	*	500 0%	500 I	N	N	*
			N 76%	2k *		2k 100%	2k I			
				4k *		4k 90%	4k I			
100	37	F	Q 44%	500 *	*	500 80%	500 I	N	N	*
			N 40%	2k *		2k 100%	2k II			
				4k *		4k 100%	4k II			
101	21	F	Q 0%	500 *	*	500 0%	500 I	N	*	*
			N 0%	2k *		2k 0%	2k I			
				4k *		4k 10%	4k I			
102	21	F	Q 12%	500 *	*	500 0%	500 I	N	*	*
			N 4%	2k *		2k 20%	2k I			
				4k *		4k 20%	4k I			

TABLE XXI (supplement, subjects 93-102)

#	Sweep Tracing Pulsed/cont. dB difference				Fixed Tracing Pulsed/cont. dB difference				Swing Width						ENT Findings
									Pulsed			Continuous			
	Type	500	2k	4k	Type	500	2k	4k	500	2k	4k	500	2k	4k	
93	II	0	8	8	II	0	10	15	8.0	8.0	9.0	8.5	7.0	7.0	Unknown
94	II	3	11	9	II	6	9	12	8.5	10.0	9.0	7.0	7.5	6.0	Unknown
95	I	0	0	0	I	0	4	3	15.5	12.5	10.5	15.5	11.5	10.0	Unknown
96	II	3	10	12	II	7	7	7	8.5	9.0	8.5	5.5	7.0	7.0	Unknown
97	I	0	8	3	I	3	8	5	8.5	7.5	8.5	8.5	7.0	7.0	Unknown
98	I	5	4	0	II	4	0	10	8.5	7.5	8.5	10.0	7.5	8.0	Unknown
99	II	0	0	8	I	0	8	4	11.5	9.5	9.0	10.0	6.5	5.5	Unknown
100	I	0	0	0	I	0	0	0	9.0	8.0	9.0	8.5	8.0	2.0	Unknown
101	I	0	10	2	II	3	6	9	9.0	9.5	9.5	8.5	7.0	5.0	Unknown
102	II	4	11	8	II	6	12	8	10.0	10.0	7.0	7.0	3.5	3.5	Unknown

TABLE XXI

DATA ACCUMULATED ON UNKNOWN GROUP, contd.

#	Age	Sex	Disc. 40db SL		- =neg.recru. + =pos.recru.	ABLB	AMLB	SISI		Owens TDT		Xray	Neuro-logical	ENG
103	45	M	Q	84%	500	*	*	500	0%	500	*	Ab	NA	N
			N	60%	2k	*		2k	0%	2k	II			
					4k	*		4k	100%	4k	III			
104	25	F	Q	100%	500	*	*	500	*	500	I	*	*	N
			N	92%	2k	*		2k	*	2k	I			
					4k	*		4k	*	4k	I			
105	71	F	Q	92%	500	*	*	500	0%	500	*	*	*	RCP
			N	92%	2k	*		2k	10%	2k	I			
					4k	*		4k	80%	4k	II			
106	58	M	Q	84%	500	*	*	500	0%	500	I	N	N	RCP
			N	64%	2k	*		2k	100%	2k	II			
					4k	*		4k	100%	4k	II			
107	58	M	Q	44%	500	+	*	500	100%	500	I	N	N	RCP
			N	40%	2k	*		2k	100%	2k	I			
					4k	*		4k	100%	4k	II			
108	69	M	Q	100%	500	*	*	500	*	500	*	*	*	*
			N	92%	2k	*		2k	*	2k	II			
					4k	*		4k	*	4k	II			
109	77	M	Q	92%	500	+	*	500	0%	500	I	N	*	N
			N	92%	2k	*		2k	0%	2k	I			
					4k	*		4k	30%	4k	I			
110	13	M	Q	72%	500	*	*	500	80%	500	I	*	*	*
			N	54%	2k	+		2k	100%	2k	I			
					4k	*		4k	0%	4k	I			
111	62	M	Q	*	500	+	*	500	0%	500	I	*	*	N
			N	*	2k	*		2k	0%	2k	III			
					4k	*		4k	30%	4k	III			
112	62	M	Q	96%	500	*	*	500	0%	500	*	*	*	N
			N	92%	2k	*		2k	0%	2k	II			
					4k	*		4k	100%	4k	III			

TABLE XXI (supplement, subjects 103-112)

#	Sweep Tracing Pulsed/cont. dB difference				Fixed Tracing Pulsed/cont. dB difference				Swing Width						ENT Findings
									Pulsed			Continuous			
	Type	500	2k	4k	Type	500	2k	4k	500	2k	4k	500	2k	4k	
103	I	0	0	5	II	0	5	10	10.5	9.5	7.0	9.5	9.5	5.5	Unknown
104	I	0	0	0	I	0	0	0	9.5	7.5	6.0	9.5	7.5	7.0	Unknown
105	I	0	0	4	II	0	14	14	10.5	6.0	6.5	7.0	4.5	9.5	Unknown
106	I	0	0	5	II	0	10	10	10.0	7.0	7.0	13.0	4.5	4.5	Unknown
107	II	0	8	8	II	5	7	8	7.5	6.0	5.5	9.0	4.5	3.0	Unknown
108	I	0	0	0	II	0	10	14	9.0	9.5	9.5	8.5	8.5	8.5	Unknown
109	I	0	0	0	I	0	5	5	5.0	5.5	6.5	5.0	3.5	5.0	Unknown
110	IV	12	7	10	II	0	7	10	10.5	9.0	8.0	8.5	4.5	4.5	Unknown
111	II	0	10	12	II	0	15	8	6.0	4.5	4.0	6.0	2.5	2.0	Unknown
112	I	0	0	9	II	3	20	10	7.0	5.0	4.0	6.0	4.0	3.0	Unknown

TABLE XXI

DATA ACCUMULATED ON UNKNOWN GROUP, contd.

#	Age	Sex	Disc. 40dB SL	- =neg.recru. + =pos.recru.	ABLB	AMLB	SISI		Owens TDT		Xray	Neuro-logical	ENG
113	76	M	Q 100%	500	*	*	500	0%	500	I	N	*	N
			N 96%	2k	*		2k	0%	2k	I			
				4k	*		4k	0%	4k	I			
114	69	M	Q 86%	500	*	*	500	0%	500	*	*	*	N
			N 76%	2k	*		2k	0%	2k	*			
				4k	*		4k	100%	4k	II			
115	69	M	Q 76%	500	*	*	500	0%	500	*	*	*	N
			N 48%	2k	*		2k	100%	2k	*			
				4k	*		4k	10%	4k	II			
116	43	F	Q 96%	500	*	*	500	*	500	I	N	N	N
			N 96%	2k	*		2k	*	2k	I			
				4k	*		4k	*	4k	I			
117	43	F	Q 100%	500	*	*	500	*	500	I	N	N	N
			N 96%	2k	*		2k	*	2k	I			
				4k	*		4k	*	4k	I			
118	44	F	Q 76%	500	*	*	500	0%	500	II	*	*	LCP
			N 56%	2k	*		2k	100%	2k	II			
				4k	*		4k	100%	4k	III			
119	49	F	Q 60%	500	+	*	500	0%	500	I	N	N	N
			N 20%	2k	+		2k	0%	2k	III			
				4k	+		4k	0%	4k	III			
120	74	F	Q 96%	500	*	+	500	0%	500	I	N	*	RDP
			N 88%	2k	*		2k	0%	2k	II			
				4k	*		4k	0%	4k	II			
121	74	F	Q 96%	500	*	*	500	0%	500	I	N	*	N
			N 92%	2k	*		2k	0%	2k	II			
				4k	*		4k	0%	4k	II			
122	44	M	Q 40%	500	*	*	500	10%	500	I	N	N	LDP
			N 36%	2k	*		2k	100%	2k	II			
				4k	*		4k	100%	4k	II			

TABLE XXI (supplement, subjects 113-122)

#	Sweep Tracing Pulsed/cont. dB difference				Fixed Tracing Pulsed/cont. dB difference				Swing Width Pulsed			Swing Width Continuous			ENT Findings
	Type	500	2k	4k	Type	500	2k	4k	500	2k	4k	500	2k	4k	
113	I	0	5	0	I	0	0	8	10.0	9.5	9.0	14.5	9.5	9.0	Unknown
114	I	0	0	0	I	0	5	7	9.5	9.0	10.0	9.5	7.0	7.5	Unknown
115	I	0	0	0	II	0	2	8	10.0	9.5	10.0	8.5	7.0	6.0	Unknown
116	I	0	0	8	II	4	7	9	7.0	7.5	715	7.5	6.5	5.5	Unknown
117	I	0	0	0	II	0	8	8	7.5	7.0	7.0	7.5	6.0	5.0	Unknown
118	II	0	6	10	II	6	9	12	7.0	7.0	4.0	6.0	2.0	2.0	Unknown
119	II	0	14	18	I	4	5	9	6.0	6.0	5.0	6.0	4.5	3.0	Unknown
120	II	0	4	8	II	4	13	3	9.5	9.0	7.5	8.0	6.0	5.0	Unknown
121	II	2	8	12	II	7	12	8	8.0	8.5	8.0	7.5	7.0	6.0	Unknown
122	II	3	7	10	I	5	7	5	7.0	8.0	7.5	7.0	4.0	3.5	Unknown

TABLE XXI

DATA ACCUMULATED ON UNKNOWN GROUP, contd.

#	Age	Sex	Disc. 40dB SL	- =neg.recru. + =pos.recru. ABLB	AMLB	SISI	Owens TDT	Xray	Neuro-logical	ENG
123	44	M	Q 16%	500 *	*	500 20%	500 I	N	N	N
			N 8%	2k *		2k 100%	2k I			
				4k *		4k 100%	4k II			
124	40	F	Q *	500 *	*	500 *	500 I	N	N	N
			N *	2k *		2k *	2k I			
				4k *		4k *	4k I			
125	24	F	Q 100%	500 *	*	500 *	500 I	*	*	*
			N 92%	2k *		2k 0%	2k I			
				4k *		4k 0%	4k II			
126	24	F	Q 100%	500 *	*	500 *	500 I	*	*	*
			N 84%	2k *		2k 0%	2k II			
				4k *		4k 0%	4k II			
127	24	F	Q 100%	500 *	*	500 *	500 I	*	*	*
			N 96%	2k *		2k *	2k I			
				4k *		4k *	4k I			

TABLE XXI (supplement, subjects 123-127)

#	Sweep Tracing Pulsed/cont. dB difference Type	500	2k	4k	Fixed Tracing Pulsed/cont. dB difference Type	500	2k	4k	Swing Width Pulsed 500	2k	4k	Continuous 500	2k	4k	ENT Findings
123	II	3	8	10	II	0	7	8	9.0	7.0	8.5	7.5	3.5	3.5	Unknown
124	I	0	3	3	I	0	3	5	9.5	10.5	10.5	11.5	9.5	9.0	Unknown
125	I	0	0	0	I	0	0	2	6.5	7.0	7.5	8.5	6.0	5.5	Unknown
126	I	0	0	0	I	0	0	0	9.0	7.5	7.0	8.5	8.5	7.0	Unknown
127	I	0	0	0	I	0	6	7	6.0	7.5	7.5	7.0	6.0	7.0	Unknown

VITA

David Warren Granitz

Birth: January 5, 1932, Ambridge, Pennsylvania.

Military Service: U.S. Navy (four years).

Wife:	Joan A. Granitz	Children:	David	Age 16
			Karen	Age 14

Education:

B. S., June, 1957, East Carolina University, Greenville, North Carolina. Major: Elementary Education, Minor: Special Education.

M. A., August, 1958, The Ohio State University, Columbus, Ohio. Major: Speech Science, with concentration in Audiology.

Professional experience:

1958-1959 - Assistant Director of Spartanburg Speech and Hearing Center, Spartanburg, South Carolina.

1959-1961 - Director of Sunnyside Speech and Hearing Center, Port Arthur, Texas.

1961-1970 - Director, Audiology and Speech Clinic, Instructor, Department of Otorhinolaryngology, University of Texas Medical Branch, Galveston, Texas.

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EXAMINATION AND THESIS REPORT

Candidate: David Warren Granitz

Major Field: Speech

Title of Thesis: An Evaluation of Diagnostic Parameters of Bekesy Audiometry

Approved:

Vincent W Byers

Major Professor and Chairman

Max Goodrich

Dean of the Graduate School

EXAMINING COMMITTEE:

Date of Examination:

June 29,1971